Geological and Hydro Geomorphological Study in Parts of Jhansi District, U.P. with use of Remote Sensing Application

DISSERTATION

SUBMITTED IN PARTIAL FULFILMENT
FOR THE AWARD OF THE DEGREE OF

Master of Philosophy

IN

GEOLOGY

By

ABDULLAH KHAN

DEPARTMENT OF GEOLOGY
ALIGARH MUSLIM UNIVERSISY
ALIGARH (INDIA)

1994

DEDICATED

TO

MY LATE FATHER

MY BELOVED MOTHER

MY BROTHERS & SISTERS

Special dedication to My beloved Bhabhi Late Mrs. Shamim Naushad whose encouragement always be remembered in my whole carrier and my life.

400615
Phone (0571) ~~25615~~
Telex 564-230-AMU-IN

DEPARTMENT OF GEOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH—202002

Dated 27. X. 94

This is to certify that Mr. Abdullah-Khan has completed his research work under my supervision for the degree of Master of Philosophy of the Aligarh Muslim University Aligarh. This work is an original contribution to my knowledge of the Geomorphological impact on groundwater resource evaluation, using remote sensing techniques in parts of Jhansi District, U.P. and has not been published any where.

He is allowed to submit the work for the M.Phil degree in Geology of the Aligarh Muslim University, Aligarh.

Dr. Syed Ahmad Ali
Lecturer
Supervisor

INDEX OF CONTENT

	Page No.
Table of Content	I
List of figures	VI
List of tables	VIII
List of Annexures	IX
Table cum Annexures	IX
CHAPTER I	1-9
CHAPTER II	10-12
CHAPTER III	13-24
CHAPTER IV	25-36
CHAPTER V	37-58
CHAPTER VI	59-77
CHAPTER VII	78-86
REFERENCES	87-89
ANNEXURES	87-103

TABLE OF CONTENT

		Page No.
CHAPTER I	-INTRODUCTION	1
	-Area & Location	1
	-Accessibility	2
	-Previous Work	2
	-Climate	4
	-Humidity	5
	-Temperature	5
	-Scope of the Present Work	5
	-Methodology (General) (Photo-Interpretation	6
	-Geology	7
	-Hydrogeology	8
	-Pedology	8
CHAPTER II	-METHODOLOGY	10
	-Material & Methodology	11
	-General Statement	11
	-Data requirement	11
	-Purpose & Objective	12
CHAPTERIII	-Remote Sensing têchniques in General	13
	-General Statement	13
	-Techniques	13
	-Aerial Photography	14

	-Satellite remote sensing	14
	-Electromagnetic technique	15
	-Sensors & multispectral Scanner	16
	-Wave length range of each MSS-bands and Its scope of application	18
	-Type of Photography on the basis of film, filter of photographic Equipments.	19
	-Radar System	20
	-Application of Remote Sensing in Ground water exploration	23
CHAPTER IV	-GEOLOGY & STRUCTURE	25
	-General Statement	25
	-Alluvium	27
	-Deccantrap Basalt	27
	-Vindhyan Super group	28
	-Bundelkhand granite	29
	-Structural Features and Lineament Study	30
	-General Statement	30
	-Structure	30
	-Joint/Fracture	30
	-Lineament	31
	-Lineament Mapping	31

CHAPTER V	-Geomorphology	37
	-General Statement	37
	-Geomorphic Units	37
	-Morphology of the Geomorphic Units & Elements	38
	-Linear ridge	38
	-Deeply Burried pedi plain	41
	-Moderetly Buried pedi plain	41
	-Shallow Buried pedi plain	42
	-Pediments/Inselberg Complex	42
	-Residual hill	42
	-Pediment Zone	43
	-Meander Scar	44
	-Residual hill	44
	-Typical Land forms observed	44
	-Old meander & meander scar	45
	-Paleochannels	45
	-Basin Morphometry	46
	-Morphometric analysis of Lakheri Sub-basin.	46
	-Linear aspects of Channel System	46
	(i) Stream order	46
	(ii) Stream Numbers	46
	(iii) Bifercation ratio	49
	-Stream length	49

	-Areal aspects of Drainage basin	53
	(I) Basin shape	53
	(i) Form factor	53
	(ii) Elongation ratio	54
	Circularity ratio	54
	Drainage density	55
	Stream frequency	55
	Infiltration Number	55
	Length of over Land flow	57
	-Relief aspects of Drainage Basin and Channel gradient	57
	Channel gradient	57
	Maximum basin relief	57
	Relief ratio	58
	Relative relief	58
	Ruggedness number	58
CHAPTER VI	-Geohydrology and Ground Water Conditions	59
	-General Statement	59
	-Quantative Geohydrology	59
	-Theis non-Equilibrium Method	65
	-Adiyalkar's and Mani's (Specific Capacity Method)	67
	-Computation of Aquiferl permeability.	75
	-Computation of Recuperation Capacities of the well	77

CHAPTER VII	-Photo-Geomorphic techniques for water targetting.	78
	-General Statement	78
	Quatitative Geohydrology	82
	Geohydrological units	82
	Granitic aquifer	82
	Alluvial aquifer	84
	-Ground Water Condition In the area	85
	Granitic aquifer	85
	Alluvial aquifer	85
	Depth to water level	86
	REFERENCE	87-89
	ANNEXUTURE I	90-94
	ANNEXUTURE II	95-97
	ANNEXUTURE III	98-99
	TABLE/Annexuture (I to IV)	100-103

LIST OF FIGURES

1. Map of India indicating Dist. Jhansi (i.e. Study area)
2. Location Map of study area.
3. Map of Bundelkhand massif showing lithology of the area (i.e. Jhansi Dist.).
4. Map showing lineaments of the study area based on land-sat TM, FCC image.
5. Rose-diagram showing length of lineaments.
6. Rose-diagram showing frequency for azimuth distribution.
7. Map showing Geomorphic units of the study area (i.e. Jhansi Dist.), based on Lansat TM, FCC image.
8. Map showing Land-form of the study area based on Land sat TM, FCC image.
9. Drainage Map of Lakheri-sub-bain in the district Jhansi (U.P.).
10. Semi-log plots of stream number vs stream order.
11. Semi-log plots of mean-stream length vs stream order.
12. Log-Log plots of stream order vs stream length.
13. Map of the Jhansi district (study area) showing the location of observation wells in the Districts.
14. Depth to water level Map of the study area in Dist. Jhansi (U.P.).
15. Theis type curve for W(u) vs U, W (u) & U units are explained in the text.

16. Time Vs Drawdown curve (Theis Method) for Pahuj-tal.

17. Time Vs Draw down (Curve (Theis Method) for Nagra-Mohalla.

18. Time Vs Drw down Curve (Theis Method) for Buya Village.

19. Time Vs Drawdown Curve (Theis Method) for Radhapur.

20. Time Vs Drawdown Curve (Theis Method) for Jakhura.

21. Time Vs Drawdown Curve.

22. Recuperation capacity Vs Residnal drawdown Curve, showing relationship between them.

23. Map showing Ground-water potential Zone of the Jhansi District (i.e. Study area).

LIST OF TABLE

I Table showing wavelength Range of MSS Bands, and Its scope of application.

II Generalized Geological Succession of the area Jhansi District (U.P.)

III Table showing Geomorphic/land forms units and its application in Ground Water potentialities, on Lansat images.

IV Table showing Stream order and bifercation ratio.

V Table showing stream length and length ratio.

VI Table showing shape-parameters of Lakheri -sub-basin.

VII Drainage dencity, stream frequency, infiltration number, length of overland flow of Lakheri-subbasin.

VIII Various parameters of relief aspects of Lakheri-Sub-basin.

IX Description of 25 observation wells of Jhansi District (we study area)

X Geohydrological units & their characteristics.

LIST OF ANNEXURES

ANNEXURES-I (Annexures) showing pumping test field data of theis non-Equilibrium method.

I a-for well No. 1

I b-for well No. 2

I c-for well No. 3

I d-for well No. 4

I e-for well No. 5

ANNEXURES-II showing field data of re-cuperation test conducted on dug-cum-bored wells (open wells).

II a- For well No. 6

II b- For well No. 7

II c- For well No. 8

ANNEXURESIII Stepwise calculation of recuperation capacity.

TABLE CUM ANNEXURE

I Showing computational results of Adiyalkar And mani's method for well Nos. (6,7,8)

II Showing computaional result of co-efficient of permeatrility (K) for well Nos. (1,2,3,4,5,8)

III Co-ordinate match points and computational results of theis non Equilibrium methods for well No. (1,2,3,4,5).

IV Details of yields charasteristics of open (Dug cum bered) wells of well Nos. (6,7,8)

V Resistivity range for various litho-units.

ACKNOWLEDGEMENT

The dissertation submitted by me for the fullfilment of the degree of Master of Philosophy. I herewith want to give my heartly thanks to those who were always ahead of me by all hands in completing my dissertation for degree of M.Phil.

At first it would be my prime right to thank Dr. Iqbaluddin, Professor & Chairman Department of Geology, who always helped me at every steps at the time of my research-work at all level. This greatness is really very much appriciated by me. I then thanks to my supervisor Dr. S. Ahmad Ali, whose skilled knowledge on the topic, and his guidence for me must be appriciated & praised at every moment, of my life. His devotion to take keen interest for completing my work is also be appriciated.

I am also thankful to Mr. Saleemuddin, cartographer & field instruction of Dept. of Geology for his great kindness & help in preparing my all maps & figures properly.

I again thankfull to my all friends& seniors specially Mr. Syed, Sayeed Akhtar (Deptt. of Geology), Mr. Arshad Zaman Khan (Deptt. of Geology). Mr. Asif (Deptt. of Geology), he is senior to me has helped me a lot for my dissertation specially in calculation of mathmetical expression for drainage Morphometry, I am thankful to all those whose name has not been coming to my mind.

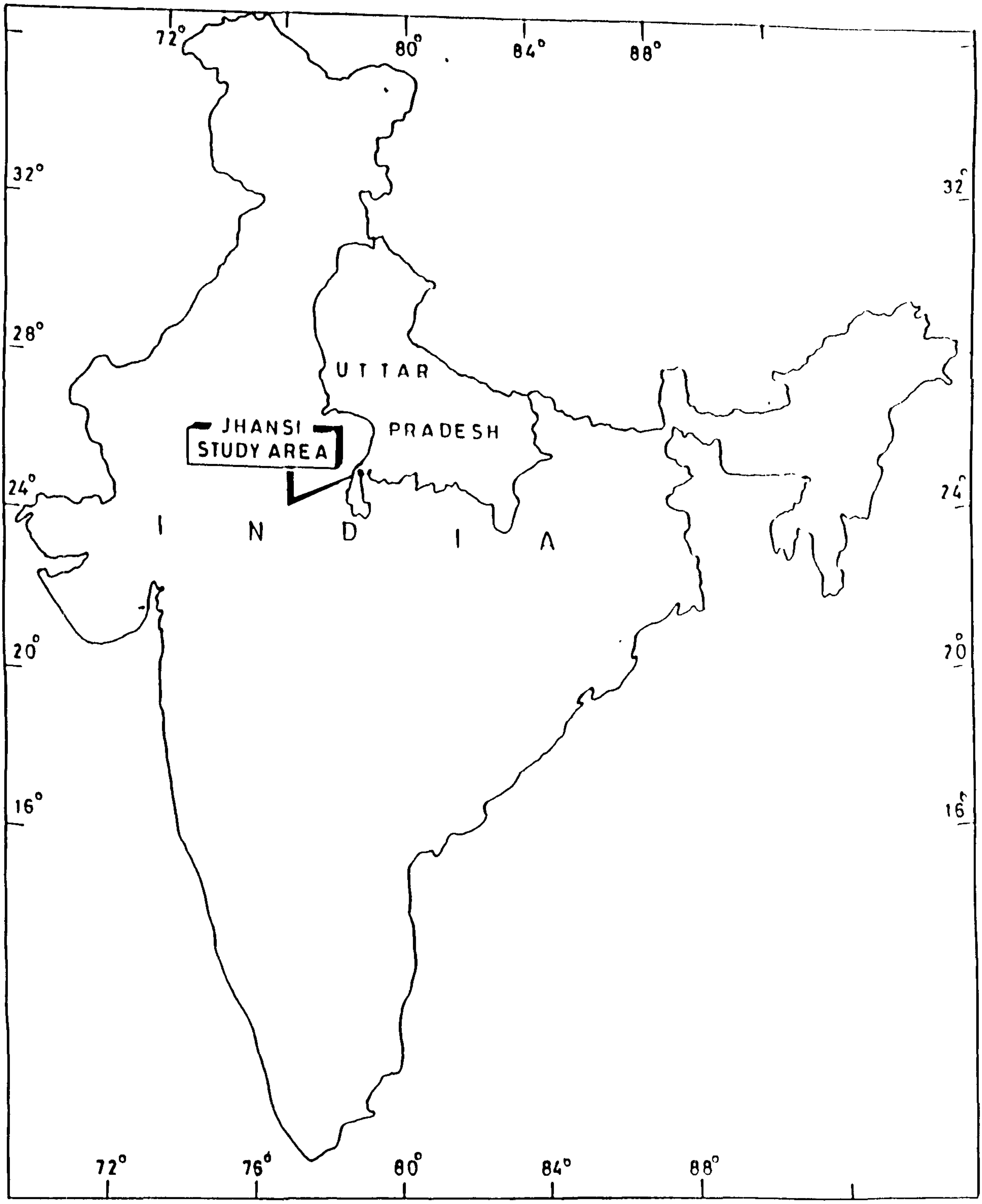
I again thanks to my supervisor Dr. S. Ahmad Ali Sb. for his great kindness and devotion for completing my research work.

Thanks

Date : 27-10-94

A. Khan

(ABDULLAH KHAN)



MAP OF INDIA SHOWING JHANSI DISTRICT (U.P., INDIA)

FIG-1

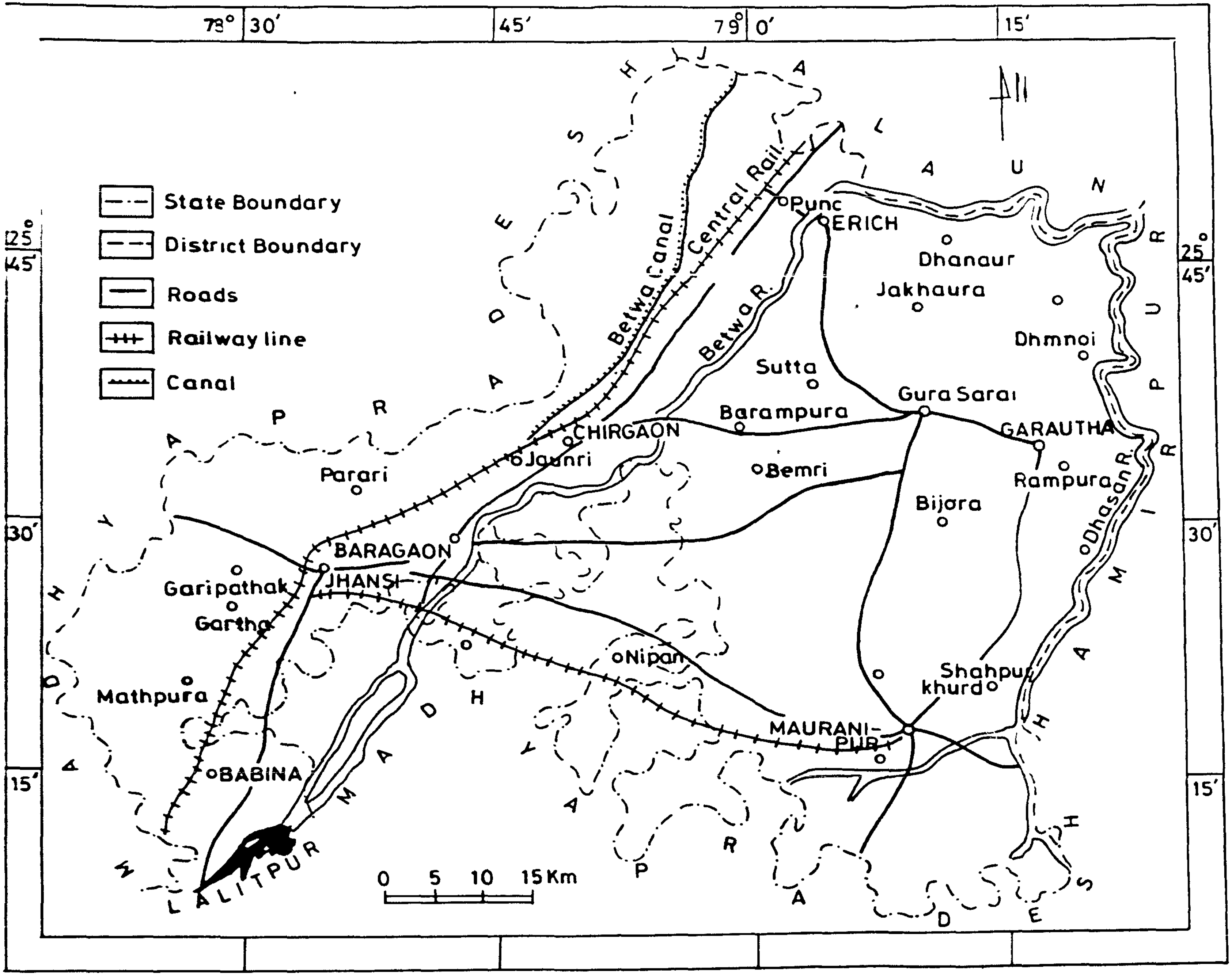


FIG-2 LOCATION MAP OF THE STUDY AREA(i.e. Jhansi District)

CHAPTER I

INTRODUCTION

General Statement

The dissertation presents the geomorphology of Jhansi district and its impact on water targetting in the area, Jhansi district, U.P. In order to develop the theme, data in respect of geology, hydrogeology were collected. The geomorphological studies were carried out through visual & some how through streo-model interpretation, with the use of Land Sat imagery and aerial photograph of the area/district. The tonal, textural, geotechnical and relief signature of the area were synthesized in terms of geomorphic elements and surfaces. The study was supported by ground truth collection in respect of litho types, hydrogeological setting, ground water potential of different geomorphic units and their pedological characters. The unifying theme of the geological, hydrogeological & geomorphological studies was evaluation geomorphic parameters for selection of well sites in hard-rock terrain, characterised by water searcity.

AREA AND LOCATION

According to survey of India, the area of the district was 3,88,5 sq miles (24,86,400 acc), at present. The district being second in area among the districts of the state, U.P. The area forms the parts of the Bundel Khand region lying between latitude $24^{o}11'$ & $25^{o}57'$ N and $78^{o}10'$ & $79^{o}25'$ longitude, and is include in parts of survey of India toposheet Nos, 54K/11' 52H/14. Here the area covered is almost Jhansi district.

ACCESSIBILITY

The area is approachable by rail from Aligarh via Kanpur. Jhansi is the district headquarter and is the nearest rail head located around 470 Km, from Aligarh. Besides Baragaon, Mathrapura, Chandpur, Mauranipur, Garanthal, Barwar, Shahpura Khurd, Jaunri & Parari etc, are the important villages in the district. Many of the villages are connected by road and cart tracts, which are motorable in dry season.

PREVIOUS WORK

The geological mapping carried out by Geological Survey of India has assinged the granite exposed in the area of Bundelkhand Granite. The radiometric dating suggests 2500 million years age for Bundelkhand granite (Cranfood 1970 and Sarkar, 1972, 1979). Sarkar (1972) correlated the Bundelkhand granite with the Sarara and Berach granites of Rajasthan. Sarkar (1979) included these granites in the upper archean. Fermor (1909) concidered the Budelkhand granite as post-tectonic to Dharwarian folding. The granite was earlier considered as basement and primordial crust but revisional mapping by Geological Survey of India has brought out that it is intrusive into the associated metasediments (Jhingran, 1958). The granite are covered by alluvial deposits which have been assinged to Quaternary era (Khan, 1978).

Mukherji (1970-71) describes a 200 m long and 2 m wide pink syenite vein in Jhansi granite at 1.3 Km N15^{o}E of 118 hill to the NE of Talbehat. Basu (1970-71) describes small vein and patches of syenitic melasyenitic rocks are commonly seen in the Jhansi granite and to a lesser extent in the Karesra granite.

Saxena (1961) & Misra & Sharma (1975) reported presence of syenites in Bundelkhand region. According to the Misra & Sharma (1975), the syenites rocks developed alongthe gradational contact of the biotite shist undergoing transformation to granitic rocks. The recognise greyish granitic syenite and choelate coloured quartz Syenite containing 10.34% and 14.83% quartz respectively. Similar syeno-granites are describe by Frestetal (1981), from the granitic terrains of Aba Al Qazaz.

Saxena (1961) mentioned extensive development of orgmatites as a stage in the transformation of biotite schist to granite at Kabrai. He further mentions migmatites at the foot of the spillway of the Kamla Sagar Dam.

Studies by Basu (1971-72; Senthiappan and Rajan 1972-73) confirms these observation, However, amagatites are not spread wide in the Kabrai area.

Basu (1970-71), Srivastava (1970-71) describe a tract of mesocratic and leucosome migmatites is noticed between Baghora and Babina. The area to the N-E of Mahoba present several type of migmatites, Including plasioclase bastite.

Basu (1970-71) describes a pegmatites body sends large feldspar crystal with section as large as E 8 cm x 4.5 cm protruding outside the body.

Basu (1970-71) also found pegmatite occurs with leucogranite at the village Utiyan. The geohydrological and hydrogeomorphological survey in parts of district was carried out by (A.K. Agarwal and D. Mishra) and by (P.N. Saha, Rajiva Mohan, P.K. Vinayan, D.N. Rao, M.B.S., Rao, S. Ravi Prakash, N.K. Goswami, C.D. Murty, A.K. Agarwal & S. Mukherjee).

CLIMATE

The climate of the district is characterised by a hot, dry summer and a cold winter. Dust storms and heat waves sweeps the area between April and June. The district records an average rainfall of 955 mm/year. Most of which is received between July and September. Analysis of rainfall data were not very clear upto the session fully. But the average rainfall of the district were 34.64". The area around Mehroni, Narhat-Lalitpur in the south record maximum rainfall. The amount decreasing towards north. The S-W monsoon reaching the district after June and withdraw by the end of September. During the period of S-W monsoon, the district received 91% of its annual precipitation.

(i) Humidity:

The air is very dry and during the summer, after noon the relative humidity is 20%. During monsoon season the moisture content is high. The average relative humidity in post-monsoon and in the winter season is generally between 50% to 65% in the morning and between 25 to 40% in the afternoon.

(ii) Temperature:

January being the coldest and May is the hotest month for this district. Maximum temp reaches upto 48^{o}C. In May and minimum temperature upto 8.4^{o}C, in January.

SCOPE OF THE PRESENT WORK

The investigation was primarily directed to evolve parameters for water targetting through technology development for the time effective and cost effective methodology. Remote sensing techniques for establishing relationship between round water localisation and geomorphology were attempted with a view to evolve photo-signature of ground water zones in different geomorphic units. In persuance of above objectives the scope of study was enlarged beyond the realm of geomorphology and hydrogeology to geology and pedology. Basic data in respect of hard rock geology and Quaternary litho-stratigraphy of the area were collected through normal survey techniques. This study was necessitated by the fact that surficial expression of the photo-recognition elements of the different geomorphic surfaces and land forms are controlled by the pedological signature and their responses to the visible part of the electromagnetic spectrum.

METHODOLOGY

PHOTO-INTERPRETATION

The geomorphological studies/geological studies were carried out through photo-interpretation techniques/ and by visual observation. The final hydrogeomorphological/geomorphological and structural maps was carried out by the following method.

The study area/comprises of entire Jhansi district, U.P. between 24°11' & 25°57'N of latitude and 78°10' & 79°25' of longitude, on survey of India topographical maps on 1:250,000 scale, were maped, for preparing base map and for carrying out field checking with the help of 1:50,000 scale topographical map. The IRS-IALISS false colour compsite (FCC) on 1:250,000 scale of postmonsoon season were used for visual interpretation of various geomorphic units, collateral data, such as ground water recharge data, postmonsoon ground water data were used for this study. The following processes were adopted for preperation of hydrogeomorphological maps.

(i) Preparation of base map from 1:250,000 scale survey of India topographical maps or degree sheet of the Jhansi district.

(ii) Collection and Study of Collection data.

(iii) Preliminary scanning of IRS FCC data and preparation of Interpretation key.

(iv) Visual interpretation of LISS II FCC data using light faste. Imagery No. (D-145-042 / D-145-043) 1989, LandSat TM Band 2,3,4

(v) Field checking in the study area for collecting ground water truth information.

(vi) Final Interpretation of LISS II data. Imagery No. (D-145-042 / D-145-043) 1989, LandSat TM, Band 2,3,4 scale correction and transfer of interpreted detaile on to base map using plan variopraphy.

(vii) Final Cartographic preparation of hydrogeomorphological maps alogwith legend.

(viii) Geomorphic features and associated Land forms having ground water potentiality can be recognised on the basis of their spectral reflectance characteristic and spatral feature present in the Satelite imagery. The classification of different geomorphic features and associated Land forms was done on the basis of tonel contrast, texture, shape, size, pattern, drainage channel configuration fluvial characteristics, sil differences erorional features and other recognition element used in terrain differentiation.

GEOLOGY

The geological mapping was carried out by visual interperpretation. From the imagery by falling their spatial feature from the Satelite imagery; on the basis of their spectral reflectance. The out crop pattern as reflected on the imagery are delineated from imagery and checked on the ground and observation in respect of lithology, texture, & structure were recorded. The structural data were collected and subjected to analytical rigour live symbol were used for graphic representation of structural data & pattern for lithomits. in the geological Maps. Samples were Collected as hand-spicimen & clips and later were studied for detailed petro-mineralogical studies.

HYDROGEOLOGY

Detailed hydrogeological studies were carried out for establishing the ogifer characteristics, water table behavious recuperation capacity, residnal draw-down Storage Coefficient, Transmissibility, Permeability etc. 25 dug well were convassed over an area of 800 Sq/cm with an average of one well/15 kms. The well were so chosen that all geomorphic limits were covered by the inyentory, besides maintaining homogeneity in their aerial-distribution.

PEDOLOGY

The samples were not collected intensionally for detailed study, but the samples are collected only to that area which are representing the various geomorphic smfaces and elements present in that area.

Chemical
But detailed study for element recognition etc. were not carried out so dissertation has lacking of it. The soil formed over the granitic terrain i.e. the weathering products of gramites, are generally earthy grey, brown, dark greyish, block, and dark brownish block in colour they conerst of caleareous concretions, angular rocks fragments and moxidused feldspar the material is genrally loose and inconesive, although occasionally they are compact and undurated the interstitial material lack feldspar fragments. The physical parametre of soil indicate that the residual soil are sandy and alluvial soils are generally silty in nature. The area occupied by alluvial soils have low permeability, their colour vary from earthy brown to grey. The earthy colour soils are charactrised of Lakheni & Dhasa surface.

The dark colour soils (grey to block) are of characteristic of Betwa surface. The pedological signature have been used to delineate the geomorphic surfaces, which by extrapolation techniques can be used for water targetting through correlation of geomorphology with geohydrological units.

CHAPTER-II

METHODOLOGY

During the course of study, the following investigations were carried out :

Survey of Indian toposheet No. 54K, 52H/14 ....were procured and a lease map was prepared using the toposheets which helped in planning of traverses in order to collect the ground water truth data. Aerial plutograph were interpreted and drainage live were mapped. on 1:60,000 scale, using mirror-streoscope. Drainage morphometry wascarried out through synthesis and quantitative analysis of the drainage map.

Visual interpretation of the following Landsat images was carried out using hand-lens and light table :

(i) False colour compositer of Landsat 5 thematic mapper mapper data on 1:250,000 and 1:50,000 scale.

(ii) MSS black and white images of bad 2 and 4 of Landsat 5 on 1:250,000 and 1:50,000 scales. Geological, geomorphological and structural details were identified interpreted and ~~deliineated~~ using standard interpretation technniques.

Preliminary geological and geomorphological maps were prepared on1:250,000 and 1:50,000 scales. The planned traverses were fallen in order to collect the ground truth which involves the checking of geological and

MATERIALS AND METHODOLOGY

General Statement

Remote Sensing techniques were taken into account for the proposed work. Airbone, spaceborn and other supplementary data were used as the basic materials for hydrogeomorphological mapping. In relation to thease various other instruments and materials were used during the course of interpretation of data.

Data Requirement

A list of various types of data needed for the present investigation is given below:

(i) Survey of India topographical map on 1:250,000 scales.

(ii) Survey of India topographical map on 1: 50,000 scales.

(iii) Black and white acrial photograph on 1:60,000 scales.

(iv) False colour composite (TMO) images of lansat 5 on 1:50,000 and 1:250,000 scales covered in path-row number

(v) Available meteorological data.

Geomorphic boundaries, various litho and geomorphic units, landcover, drainage behaviour, presence and absence of joints and fractures in water bea ing horizon and their attitudes. Twentyfive observation wells were selected and their water level and other related parametres, were collected.

An effort was made to observe the behaviour of ground water in the aquifere of different geomorphic units. Depth to water level and water table maps were prepared on 1:50,000 scales. The preliminary maps were modified on the basis of ground truth data and thus final maps were prepared.

The ground water potential zones were delineated by superimposing an overlay of geomorphic indicator over the geological map showing lineaments. Fig. shows a summary of methodology in the form of flow chart.

PURPOSE AND OBJECTIVE

Selection of Data

TOPOSHEETS (1:250,000 1: 50,000)	REMOTELY SENSED DATA PROCUREMENT
PREPARATION OF BASE MAP	OPTICAL ENHANCEMENT TECHNIQUES
TRASFERIN OF INTERPRETED DATA ON BASE MAP	VISUAL INTERPRETATIO OF AERIAL PHOTOGRAPH AND SATTELLITE IMAGERY

DELINEATION OF GROUND WATER POTENTIAL ZONES

DISSERTATION

PRELIMINARY GEOLOGICAL
AND
GEOMORPHOLOGICAL MAPS

GROUND TRUTH DATA COLLECTION

MODIFICATION OF PRELIMINARY MAPS

FINAL MAP PREPARATION

Fig. (SUMMARY OF METHODOLOGY)

CHAPTER-III

Remote Sensing

Techniques used for PHOTO - INTERPRETATIONS

General Statement

India is one of the largest countries in the world. Which is endoved with abundunt natural resources, although much of this natural resources or wealth has remained unexploited. One of the seniour problems to obtain the fullest benefit is the improper exploration and exploitation of mineral and other earth resource. The remote sensing techniques with the geophysical survey hasrevolutionised geological exploration. The techniques of remote-sensing hasmade available to man a macroscopic synoptic view for the first time in several bandsof eleetromagnetic spectrum. The new morpho-tectonic theories have been superimposed on the earthen understanding of metallogenic maps, giving rise to new conceptnal models of mineralization. On a far clear understanding of the actual structure andgeomorphology involved.

Techniques

(i) By Aeroplane

(ii) By Sattelite

MODERN TECHNIQUES IN PHOTO-INTERPRETATION

(iii) Electromagnetic Spectrum

(i) Colour (ii) Infra-red (iii) Colour-Infra-red

(iv) Multibrand photography (v) Radar.

(vi) Thermal infra-red imagery.

(iv) Orbital Satellite

MSS (Multi Spectral Scahner)

(1) Aerial Photography

The technique used for the purpose of availability of information of remotedly areas by the use of aircraft is called Aerial-Photography.

The recently developed techniques used to get full information of areas, which is beyond the reach of human eyes are aerial-photography, photogrammetry and aerial photo-Interpretation. Their development has closely been connected with the development of aeronamtics, high precision aerial cameras and photogrammetic & photo-Interpretation istruments.

The photographic interpretation is an act of examining these photographic images for the purpose of identifying objects and judging their significance.

Photogrammetery is the art of making reliable mesurments from the air photographs.

(2) Satellite Imagery

A satellite imagery is the photographic image of the earths surface usually taken fromsatellite, fixed in orlett or in space.

The advent of photographs and Multi spectrol scanner (MSS) imageries has been opend from orbital satellite.

More systamatic coverage of the earth surface was made by the first earth resource technology satellite ERTS-1 (later renamed as Land sat-1) which was launched on July 23, 1972. Land sat-2 waslaunched on January 22, 1975. The NASA (National Aeronautics & space administration) unmanned skylab space vehicke was placed in orbit in May 1973. Subsequently, the manned space vehicle skylab 2 was launched on May, 1973, & after then skylab (3,4) had been launched. The result of Land sat series have virtually revolutionized the field of remote-sensing, particularly for natural resources survey.

ELECTROMAGNETIC SPECTRUM TECHNIQUES

New techniques have been added to the traditional one of black and white photography exploiting a much wider part of the electromagnetic spectrum, namely, colour, infrared, colour infra-red, multiband photography and radar and thermal infra-red imagery. An early and still most usefull form of remote sensing is photography, which records the scene, as man seep it, on film sensitive to that part of the electromagnetic spectrum caved visible energy.

Electromagnetic spectrum is fundamental base of remote sensing from aeroplane & setellite. The electromagnetic spectrum covers the entire range wavelength & frequencies, which travel in waves of various lenth; mast of which are imisible to human eye. Wavelength propressively longer than those that the eye can see are infra-red and micro waves. Wave length propressively shorter than those that eye can see are ultra violat, X rays and gamma rays.

Sensors and Multispectral Scanner

Instrument or sensors can produce photographs and image of energy distribution on the Earths surface in the certain parts of electromagnetic spectrum. These instruments include photographic cameras, scanning radiometers and radar. Each part of the electromagnetic spectrum is particularly suitable for providing information about certain aspects of the earth's surface.

Remote sensing is divided into two categories-

(i) Active (ii) Passive

(i) In Active Remote Sensing, a specific part of the electromagnetic energy is produced from an artificial source, projedt towards an area of interest.

(ii) In Passive remote sensing their is no any artificial energy derived from the sun.

Most of the commonly used aerial-photography such as panchromatic, Infra-red & colour Infra-red & colour uses this energy falling on the surface of the Earth.

Multispectral scanner (MSS) It is a live scanning device, which simultaneously scans the terrains passing beneath the space-craft or the aeroplane the function of the scanner is to produced different synchronous images each at a different wave bands.

The Land sat (1,2,3) are fitted with MSS, which have oscillating mirrors that sean the earth's surface below the moving satellite. Natural energy reflections or radiations camming from the surface of the earth and its atmosphere arereflected by the unirror into a feflecting telescope and focussed on fibre optic bundles located in the focal plane of the telescope. Radiation is conducted by the fibre-optic light pipes to filters that permity only certain wavelength of radiation to strike the detectors. The voltage produce by each detectors is related to the amount of radiation that reaches the detector. Each detector is capable of producing voltage from Zero to Five volt. 24 detectors are used on the MSS to record the six line of data in four wavelength bands.

Each remote sensing satellite such as Land sat carries three data acquisition system i.e. a Multi spectral scanner (MSS), designed for four spectral bands, A return bean Vedicon (RBV) or television system and a data connection system (DCS) to relay environment data to and fromground based data connection plateform.

The multispectral scanner (MSS) is the primary sensing system and acquires images of 115 miles (185 kms) per side in four spectrol band in the visible and near Infra-red region of the electromagnetic spectrum. The wavelength range of each band and its scope of application is give in table.

For Geological investigation MSS and NOSS and 6 and found quite suitable as they provide best information on the geology, geomorphology, regional structure, soil variation, soil moisture and good land water-vegetation contrast of the region.

The wavelength range andtheir scope of application are listed below in the table (I).

WAVELENGTH RANGE OF EACH MSS bands

AND

ITS SCOPE OF APPLICATION

BAND NOs.	WAVELENGTH RANGE	APPLICATION FOR REMOTE SENSING PURPOSES
BAND 4 (Green)	0.5 to 0.6 micron	Good for discriminating the depth, turbiolity of water
BAND 5 (Lower red)	0.6 to 0.7 micron	Best for showing topographi andvegetal flanture
BAND 6 (upper red and) Lower Infra-red)	0.7 t0 0.8 micron	Best tonal contrast, which reflects like soil, soil moisture Irrigation and geology & drainage study.
BAND 7 (Infra-red)	0.9 to 1.1	Good for Land and water discrimination & hydrological studies.

TYPES OF PHOTOGRAPHY ON THE BASIS

OF

FILM, FILTER OF PHOTOGRAPHIC EQUIPMENTS

S.No.	Type of photography	Spectral characteristics	Suitability
1.	Panchromatic	Recurds all the reflection of visible spectrum	most suited for photo-interparation
2.	Infra-red	Records only Red and Infra-red part of the spectrum	suited for water water vegetation discrimination
3.	Colour	Record all the reflection of visible spectrum in colour or rear natural colour.	in mineral-prospecting, forestry, agriculture, Industry & town planning.
4.	Colour infra-red	Records spectral colour and infra-red in combination, resulting in false colour.	for plant & crop diseases land-water vegetation discrimination, water pollution
5.	Thermal infra-red imagery	Records only the thermal Infra-red emission of objects	for study involving Temperature variation, water pollution.
6.	Radar Imagery	Records reflections of radar waves.	suited for topographic studies, Morphotectonic studies and general condition of ground.
7.	Spectazonal	Records only the setective part of the spectrum	Different parts of the spectrum is suited to different aspects of studies.

Radar System :

Radar (radio detection and ranging) is an active remote sensing system which operates in the microwave portion of the electromagnetic spectrum. The wavelength ranges from 0.1 to 30 cm.

Radar imaging system provides a source of electromagnetic energy to illuminate the terrain and energy returned from the terrain is detected by the system and recorded as imagery.

Different types of the imaging and non-imaging radars have been developed for active remote sensing system for a variety of applications. The imaging radars include Side-Looking airborne radar (SLAR) and Synthetic aperture radar (SAR). The non-imaging radars are Scatterometer. Two frequency Scatterometer, Radar spectrometer and Altimeter.

During second world war, radar was developed for locating target and navigation purposes where the circular cathode-ray-tube (CRT) and rotating antenna were used. In 1950s, the

Side-Looking airborn radar (SLAR) was developed in order to take reconnaissance images for military purposes. The Synthetic aperture radar (SAR) has been recently developed with the higher degree of spatial resolution of 6 to 10 meters. It is useful for geological studies and works in all season, irrespective of weather condition.

The amount of energy reflected from the terrain to the radar antenna is known as radar return. The parameters strongly affect the radar return includes polarisation, depression angle, wavelength, detection constant of surface material and surface roughness etc. Stronger radar returns result in the light tone and indicate the predominance of cultural features. The intermediate returns resulting in the production of medium tone on the image, which infer to the areas of open country whereas weaker or no return results in dark tone suggesting the presence of water body or hydrogeologic features. Most of the available images have been acquired by Ka band, X band and L band.

The wavelength of different band is as follows :

Band	Wavelength (cm)
Ka(0.86 cm)	0.8 to 1.1
K	1.1 to 1.7
Ku	1.7 to 2.4
X (3.0 and 3.2 cm)	2.4 to 3.8
C	3.8 to 7.5
L (25.0 cm)	15.0 to 30.0
P	30.0 to 1000.0

The radar image is very useful in deciphering the presence of fault and estimating the soil moisture. It is supplementary to normal photography owing to its operation in the areas of unfavourable weather conditionstoo.

APPLICATION OF REMOTE SENSING IN GROUNDWATER EXPLORATION

The remote sensing techniques have proven their worth in exploring the groundwater resources very well on account of its cheaper cost, large information and storage capacity etc. The geomorphology and study of fracture pattern (in hard rock areas) have become the powerful aiding tool in obtaining the information about the hydrogeologic properties of the formations. The major advantage of this technique is that the groundwater surveys are conducted in a relatively shorter time than that of conventional methods.

Aerial photographs were used for groundwater exploration for the first time in the year of 1950. With the successful launch of Landsat-I on 23rd July, 1972, it has become possible to map the potential zones of groundwater with the help of satellite image. Hawe, R.H.L. (1958) has give the procedures to apply air photo interpretation in locating the groundwater. The basis for hydromorphologic mapping in various areas viz; mountaineous, alluvial, hard-rock and coastal terrain is described by Roy, A.K. (1972, 1976, 1979) and Sharma, S.K. et. al., (1975). Sharma, (1984) described the procedures of groundwater studies and made a survey of remote sensing applications over fissured formations of the Indian Peninsular shield. Roy (1984) described the main trends of

air-borneand satellite remote sensing applications for groundwater exploration as,
(i) mapping of drainage and drainage network analysis,
(ii) mapping of landforms, landuse and changes therein,
(iii) geologic and structural mapping vis-a-vis groundwater controls, (iv) mapping vegetation and drainage anomalies as indicators for groundwater (v) evaluation of soils (hydrologic soil groups) and soil moisture conditions and (vi) delineation of groundwater potential zones based on geologic as well as landscape indicatory studies (hydromorphogeology).

Interpretation of aerial photographs with ground truth data provides adequate information about the hydrogeologic properties of the rock formation. False colour composites and Thematic Mapper data appear to be most useful for the mapping of hydrogeomorphological units. Thermal infra-red images also used to map the temperature variation of ground surface enable to evaluate the groundwater resources. The moisture content of the rock can be mapped by the radar images, gives possible clues about the hydrogeological properties of the formations.

From the preceeding discussion it appears that the knowledge of geology and structure, geomorphology, landform, drainage, vegetation, climate of the area, landuse, lineaments and their intersection (in case of hardrocks) is required in order to evaluate the groundwater resources to have maximum desired information through the integrated approach.

CHAPTER - IV

GEOLOGY

General Statement

The study area Jhansi District Comprises of Bundel Khand granite massif the following generalized geological succession table (II) has come up on the Basiscof the interpretation of land sat images and aerial photographs with limited field check.

TABLE- II

AGE (Yrs.)	FORMATION	LITHOLOGY
Recent	ALLUVIUM	Alluvium Comparising of Sand, Silt and Clay .
uppcret to Lr Eocene	(Malwa) Deceantrap	Basalt.
1500-550 mg.	Vindhyan Supergroup	Metasedimentary rocks
2600 mg.	Bundel Khand gramitic Complex	gramite & veng Cow Gneis

The photo characters of litho units identified from the denial photograph and sattellite imagery are given in the table ( ) respectively and discussed as follows.

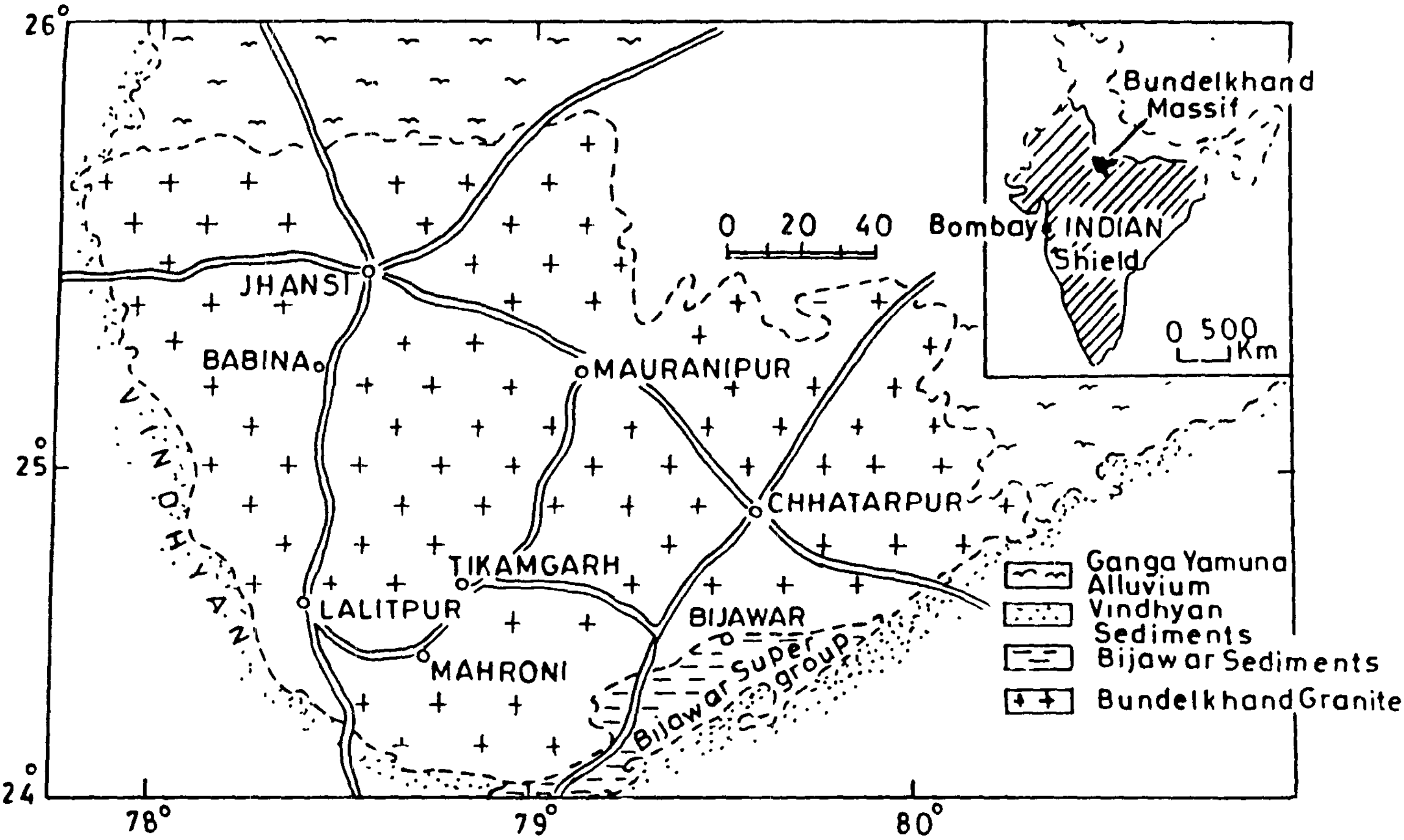


FIG-3

MAP SHOWING LITHOLOGY OF BUNDELKHAND MASSIF IN UTTAR PRADESH

ALLUVIUM Alluvium appears as medium to dark grey in tone on aerial photographs, hight on black and white image and reddish grey to red colour on false colour composite, in areas where alluvium iscovered by natural vegetation. It is charactrised by sub-dendric drainage pattern but combination of dendric to rectangular drainage pattern is also seen at places.

The Narrow patterns of alluuium have been identified through land sat images, confining along the rivers and streams (fig. 3). The thickness of alluvium is comparising of five sand, silt and clay prbably due to result of fluvial action.

Deccan trap Basalt.

The very minor portion of study are a i.e. Jhansi district is covered by Deccan basalt. By photointerpretation the basalt has been identified on the Betwa river near Jhansi. Basalt snw light to dark tone on black and white images and dark grey on flase colour composites. The lithounits is characterised by sub-dendritic drainage pattern but a sort of intermix (dendritic & rectiongular) drainage pattern is commonly observed in which lower order stream form dendritic pattern white high order stream constitute rectangular pattern. This unit is overlain by alluvium of variable Geology thickness. The deneity of drainage varies from low (on the flat to slightly undulating top sunfaces) to high (on the dossected mergin).

A number to tongue like features and cirrated mergin are identified and recognised on the landsat images and on aerial photographs. These feature are very helpful in identifying the Deccan trap terrain. However, it appears difficult to map the individual flow through lansat umages or my aerial photograph, because of land use pattern and low antcrop elevations.

Vindhyan supergroup The District Jhansi is also Comparises of Vindhyan supergroup sediment of upper protrozoic rocks. It isoverlain by Decean trap. The photointerpretion of these Metasedimentary rock reveal the characteristics of its litho units and other quality of rock like porosity, perviousity etc.

It show dark grey tone on aerial photograph and reddish grey to be on black and white images and dark red to dark grey on false colour composite.

The lithounits is charactrised by dendritic to sub-dendritic pattern and combination of rectengular and dendritic pattern. The Vindhyan supergroup of sediments are interpreted SW. of Jhansi City. It whows great diversity for water body or reservirv. The toral characterstic of rocks exhibit the storage capacity ofthis group of rocks and so it resemble porous rocks The darker tone is characterised of great tracturing and faulbring into the strata so the rocks kas secondary porosity, which gives the ideal of good reservoir of water in the south west of the district Jhansi. The major tal andReservoir in the NW of the district may be due to the presence the Vidhyan super groups rocks.

Bundel Khand gramite

The major and extensive part of the Jhansi district is covered by the Bundel Khand gramite. The toral, textural and other photo images after interpretation exhibit the all characteristic of these gramite. The dark grey tone exhibit the course grained gramitic rock and the texture of drainage is also uneven which reveals the textural characteristic of the Bundel Khand gramite i.e. Bundel Khand gramite is unierous-cally sound. The drainage pattern is not fully dentrictic, which shows that the stream are not fully satureted with water or the water storage is poor in the area due to presence of liveaments, quartz reeb in the SE part of the district the drainage pattern is commonly observed Geology in which were order streams form denritic pattern white higher order streams constitute light grey tone exhibit the fracturing in the gramitic rock but not very extensive fracting is observed.

The Bundel Khand gramite is also very Diamond in minorological character.

( )

( )

( )

( )

( )

( )

STRUCTURAL FEATURES AND LINEAMENT

STUDY

General Statement

A lithological map has been prepared to demorcate the major lithological units and a land form map isprepared with the help of aerial photograph and Land sat images have been studied in conjunction with the lithological map to understand the ground water poentiality of the different land form, similarly the structural map has been made to demarcate Fracture, liveament or joints if any with the help of Land sat images to estimate the ground water obsurdance in the hard rock terrain.

STRUCTURE

The structural configmation of the area is conceated in most parts due to widespread blanket of alluvium. However Bundel Khand gramite, at places exhibit foliation, cleavage, joints shears, Fractures, Faults & liveaments.

Joint/Fracture :- The gramitic out crops exhibit well developed joints. The morphology are present in the area as tensile fractures charactrised by clean granular break. The fracture surface are planner and homogenous at places failure surface exhibits fracturing across the grain. The joints are mostly light at the deeper levels but at outcrop level those appear as open fractures. Geometrically these are systamatic joints. On the basis of the inclination of the failure surface, these fractures vary from sub-horizontal to sub-vertical joints. The open fracture after filled by secondary clay at places. Some-times sweet-in type quartz veins have healed the fractures. The joints exhibit extreme variation in the azimuth and dip.

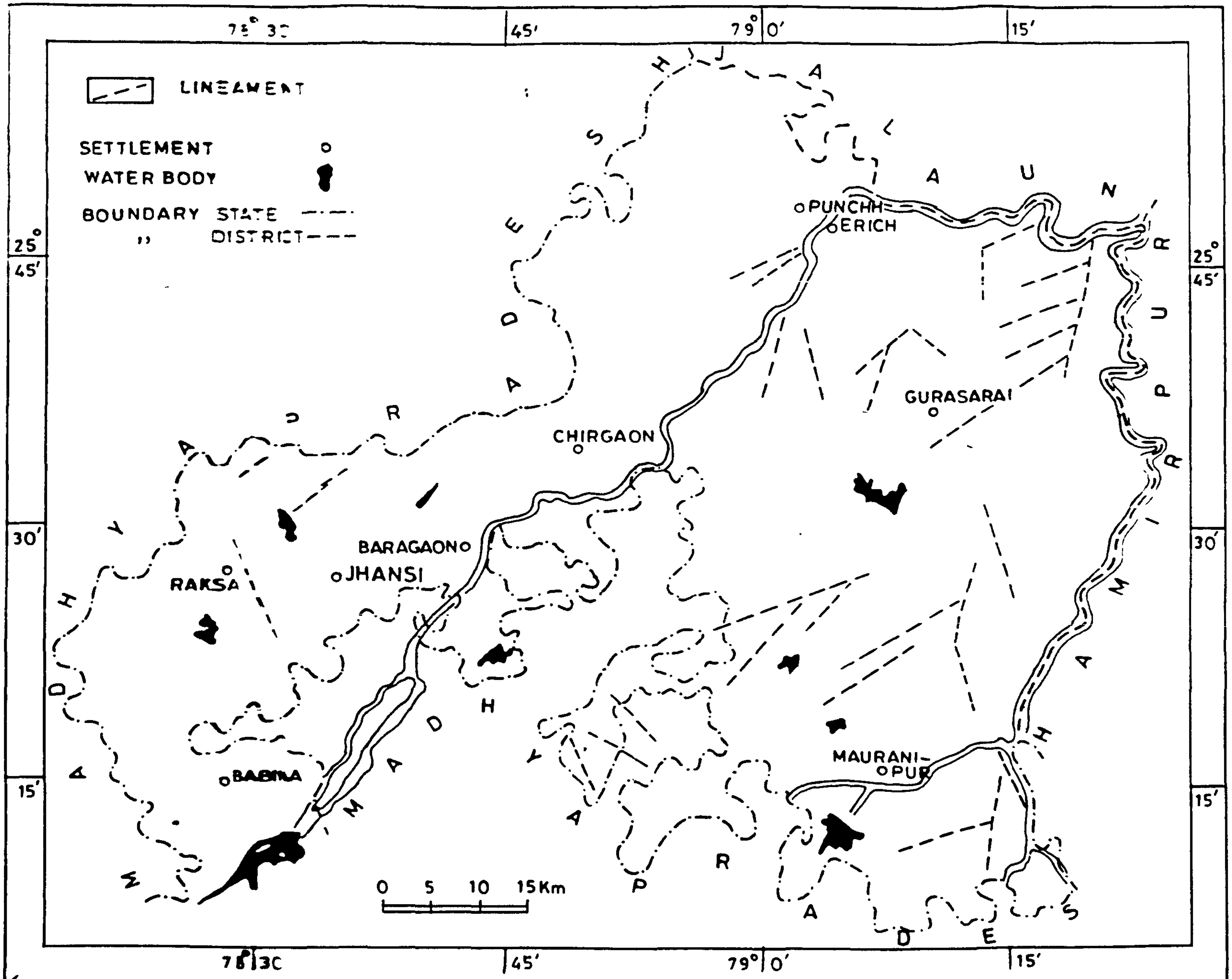
LINEAMENTS

The ground water abundence in hard rocks depends not only on rock types but also on the intensity of tectoric activity. The storrativity of a hard sock aquifer is of very complex nature as the rock itself is impervious and the occurence and movement of fracture system. In this context mapping of fracture & lineaments give a clue to the occurence of ground water in hard rock terrain.

Lineament Mapping Since the advent of remote sensing technology, various workers have emphasized the importance of aerial and sattellite image in structural analysis, espiecilly in the lineament-tectonic mapping for ground water targetting (Boyer and Mc Queen 1964, Lattman & Parizek 1964, Trainer & Elison 1967, Siddiqui & Parizek 1971).

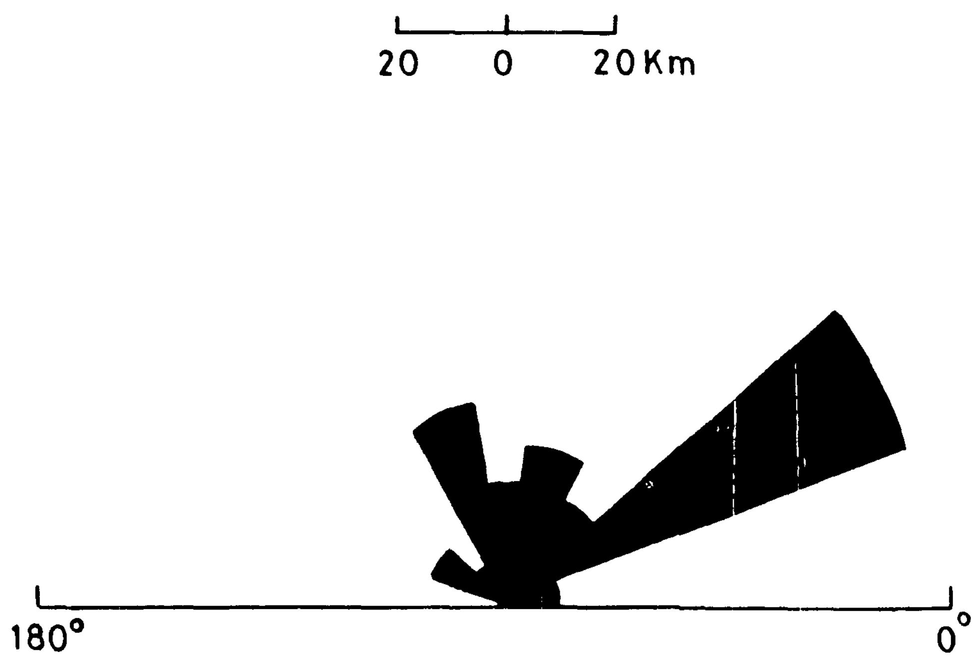
A liveament is a mappable, simple or composite linear feature of a surface, whose parts are aligned in rectilinear or slightly cuvvilinear relationship and which differs distinctly from the pattern of adiacent feature and presum ably reflects a sub-surface phenomenon (O'heary et al 1976). Lineament are not necessarily fracture in rock.

In general fracturesor lineament that locolize ground water have an expression ground surface. This has been represented by the topographic depression or different soil



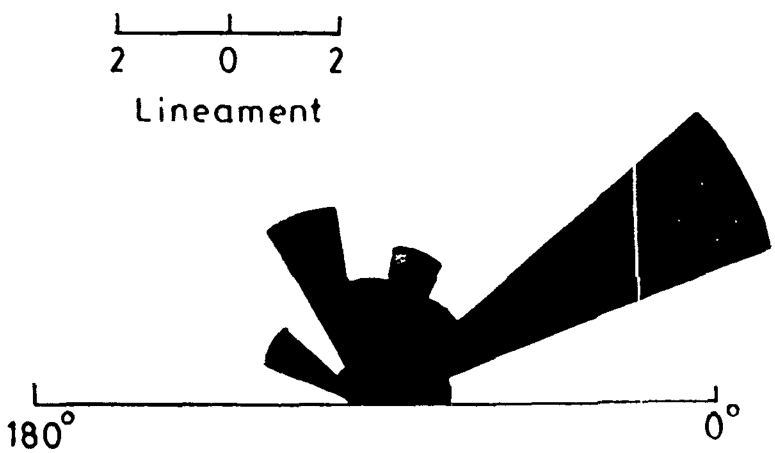
MAP SHOWING LINEAMENTS OF THE STUDY AREA (i.e. in parts of Jhansi District, U.P.)

FIG-4



Rose diagram for Length of Lineament

FIG- 5



Rose diagram showing Frequency diagram for Azimuth distribution.

FIG-6

tone and vegetation anomally.

A lineament tectonic map of the area has been mapped and shown in fig- 5&6 , showing the major and minor lineaments, faults in the district Jhansi of Bundelkhand granitic region, using landsat imagery.

The extension of lineaments to the south and south western part of the hard rock area, through the pediment zone has also been shown which exhibit that the river of Lakheri and other tributries are lineaments and the presence of pediment zone in the way of extension of lineament indicate that the water level ot the Lakheri basin is very low the aquifer characteristic of that basin is of semiconfined aquifer, so the prospects of groundwater is low in this basin of hard rockarea. The quarts reef present in the fracture of granitic rock resist the water to pass from pore spaces. Here we find the bend storage co-efficient of hard rock like granitic rocks. May be included the lineament having more than 150 m length have been also considered for mapping. In total, about 32 such lineaments have been mapped from this area. The longest lineaments pickedup has 1730 m length with an orientation of E21^{o}S-W21^{o}N, extending between the village charhraudhawari to Dogra the major directions of the lineaments have been plotted in rose diagram Fig. 6 It has been observed that the majority of the lineaments are oriented in N-E and SE direction i.e. they are parallel to the strike direction of the fault and are probably syngemetic and sympathetic fracture formed due to faulting.

In different localities like Garautha, Guresarai, Chtragaon, punch, the lineament and joints are generally oriented E-W direction they are almost parallel and occur wide apart from each other, this indicates that they are tensional fracture. As tensional fracture are open in mature, they should form good conduits for ground water occurrence and movement. Weathering is prominent along the fracture, which give additional opportunity for the accumulation of ground water. The places where tensional fractures get intersected are the ideal site for ground water targeting. For example, it is Sutta, four fractures with different orientation intersect each other Fig. 4 This appear to the an ideal site for well location. In addition to this, buried pediment zones having intersection of fractures like village Raksa in the map, FIG-7 , are also ideal locations for groundwater.

The tensile fracture and joints are potential zones for ground water.

CHAPTER-V

GEOMORPHOLOGY

General Statement :

Geomorphic study of Jhansi area; In Uttar Pradesh was carried out through photo-Interpretation techniques, in an attempt to establish correlation between land forms and hydrogeology, with the ultimate adjective using geomorphic unit as guide for ground-water development. The study represent an account of the constructional and erosional land forms, their photo-character and geo-technical signatures.

Geomorphic Units :

The area has been delineated into six major geomorphic units. Homogeneity in the level of erosion, genetic and temporal correlation and slope characteristics with in the zone have been used as parametre for the delineation of zonal boundries.

Table- III gives the Geomorphic units with their description & Ground water properties.

TABLE III

MAP UNIT	GEOMORPHIC UNIT	DESCRIPTION	GROUND WATER
LR	Linear Ridge of Quartz	Steep-sloping trending NE-SW forming natural water barriers	Poor
BPP-D	Deeply buried, weathered pediplain over Granite	Thick occurence of soil, Flat cultivated Lands.	Good to excellent

BPP-M	Moderetly Weathered buried pediplain over Granite	Flat terrain with moderate erosional surface spacely vegetated	Moderate to Good
BPP-S	Shallow weathered buried pediplain over Granite	Flat terrain with low lying Areas and thin soil over.	Poor to Moderate
PI	Pediment Inselbergs Complex over Granite	Gently sloping broad erosional surface or plain of low relief with Hillock of granite	Poor
RH	Risidual Hill	Hill formed by the debris of rock at that place of weathing	Poor

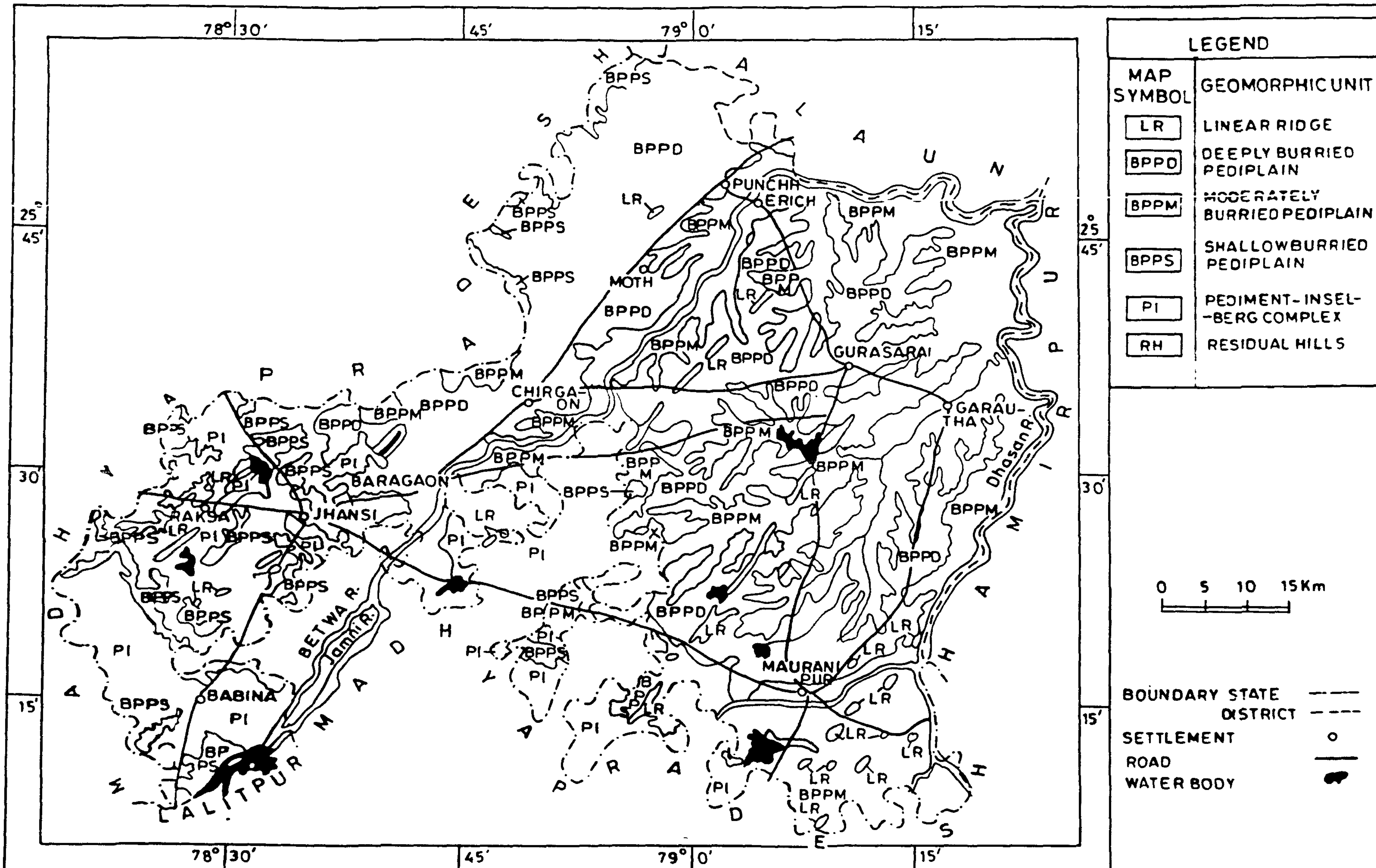
MORPHOLOGY OF THE GEOMORPHIC UNITS AND ELEMENTS :

Land form characteristic around Jhansi district and their rivers vallies, their composition and spatial distribution have been described in Geomorphic unit description in Table( )

The actual disposition of the geomorphic elements spatially associated withdifferent geomorphic units has been presented in Fig.(7).

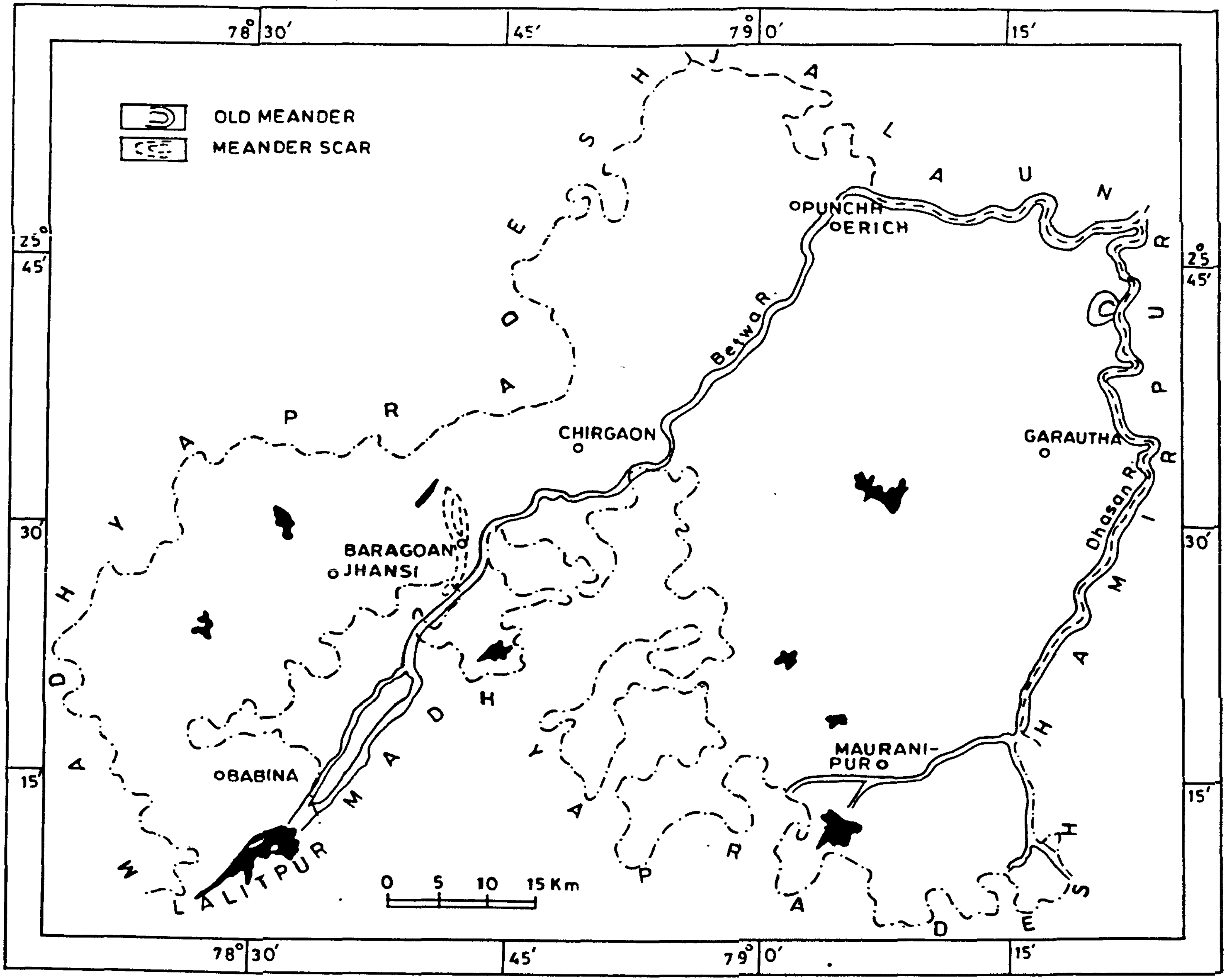
LINEAR RIDGE :

This unit represent the NE-SW trending quartz-reafs. It is linear, elevated and sharp at the crest. The reefs act as a barrier for ground water movment and often form favourable sites on the upgradient side for the occurence of ground water.



GEOMORPHIC MAP OF THE STUDY AREA (i.e. in parts of Jhansi District, U.P.)
LANDSAT TM, FCC IMAGE

FIG-7



MAP SHOWING LAND FORMS OF STUDY AREA (i.e. in parts of Jhansi District, U.P.)
LAND-SAT TM, FCC IMAGE

FIG-8

The granite outcrops occurs as linear-ridge when the quartz is intrude in between the fracture zone and forms reefs, near the Mauranipur at the site of Dhasan river basin. However the reefs themselves are not suitable for occurence of ground water. The presence of lineaments is an important factor to be considered specially when it posses through the pediments. However the linearments occuring in the pediment residual hill complex region were found dry . As at Nauranipur region of Jhansi district is dry, the aquifer propety for this area is not suitable for water potential.

DEEPLY BURIED PEDIPLAIN : T

This unit is represented by BPP-D in Map (Central highly eroding composite plain, NRSA, 1980), lying in the eastern part of the Jhansi town is charactrised by its reddish colour, cultivated field, smooth texture and poor drainage patter. The Infiltration rate is high & thus excellent ground water recharge takes place. The Buried-pediplain near Barwar main canal joining Lakheri river, (a tributing of Dhasan) near Garautha, (eastern part of the district) is prominent, for Ground water potential. Here ground water occurs in weathered mantle and in joints and fractured granitic rocks of this area. Such area is also located in lineaments zones.

MODERETLY BURID PEDIPLAIN :

This unit occuring in North-East and North-West part of the Jhansi City is characterised by reddish colour due to cultivated lands, smooth texture and fine drainage pattern. It has got moderate to excellent infiltration capacity and thus has good recharge to ground-water.

SHALLOW BURIED PEDIPLAIN :

The unit BPP-S has been interpreted on the basis of its whitish red colour, sparse vegetation, smooth texture and moderate drainage pattern. This unit is mainly observed in the sourthern part of the district and at places in patches in the northern part. It has low to moderate infiltration capacity and thus has moderate recharge to ground water. The area where the shallow buried pedi-plains (BPP-S) were observed prominent are Jhansi-Gwalior railway line near Pahuj reservoir. & near Babina town; in Jhansi Dist. It is mainly observed on the Jhansi-Lalitpur road side.

PEDIMENT/INSELBERG COMPLEX :

These two unit as observed and combined in a single unit as the pediments is the low relief plain in and to semi-grid region due to erosion, at the base of asrupt hilly front. Some times a knolear residual hill may developed abruptly from a low land erosion surface. These were occuring widely inthe district and interpreted on the basis of its reddish-white colour, almost no vegetation, uneven texture, and typical dendritic drainage. The rocks are contact hard and poor in primary porosity and thus have poor recharge of ground water. It raises to an elevation of 190 m above mean Sea level the top.

RESIDUL HILL :

It has been also observed with the pediment and Inselberg with same tonal, textural quality with denritic drainage pattern.

SHALLOW BURIED PEDIPLAIN :

The unit BPP-S has been interpreted on the basis of its whitish red colour, sparse vegetation, smooth texture and moderate drainage pattern. This unit is mainly observed in the sourthern part of the district and at places in patches in the northern part. It has low to moderate infiltration capacity and thus has moderate recharge to ground water. The area where the shallow buried pediplains (BPP-S) were observed prominent are Jhansi-Gwalior railway line near Pahuj reservoir. & near Babina town; in Jhansi Dist. It is mainly observed on the Jhansi-Lalitpur road side.

PEDIMENT/INSELBERG COMPLEX :

These two unit as observed and combined in a single unit as the pediments is the low relief plain in and to semi-grid region due to erosion, at the base of asrupt hilly front. Some times a knolear residual hill may developed abruptly from a low land erosion surface. These were occuring widely inthe district and interpreted on the basis of its reddish-white colour, almost no vegetation, uneven texture, and typical dendritic drainage. The rocks are contact hard and poor in primary porosity and thus have poor recharge of ground water. It raises to an elevation of 190 m above mean Sea level The top of the Inselberg is relatively reunoi flat defined by 180m contours. At Bara Gaon, the granite forms two Isolated Inselbergs emerging from beneath the month of the wathered granite. under the streo-model. It is recognised by the sleep slopes, medium drainage & sporse bushes etc.

PEDIMENT ZONE : Isolated occurence of pediments have been recorded around the Jhansi & Lalitpur. The geomorphic unit has a horse-shoe shape boundary outline, extending from Raksa to Lalitpur, covering from the area of several sq km. The pediments has been buried by soil alluvium and colluvium and vs characterised by soil alluvium and colluvium and vs characterised by moderate slope 5^0 to 13^0. The slope is radially disposed with respect to Jhansi-Lalitpur Inselberg under the steromodel the pediment is characterised by sloping land forms, having radial slopes with centrifugal surface drainage.

Meander Scar

The spatial disposition of channel or scar North-east of Jhansi dist. suggest east ward migration of the Betwa river during recent geometrical post.

RESIDUL HILL :

It has been also observed with the pediment and Inselberg with same tonal, textual quality with denritic drainage pattern. It has been observed very rare in the South-eastern part of the district near South of Mauranipur. It has poor ground water recharge capacity due to absence of lineaments, paleochannels meader scars and point bar etc. In streomodel. It is recognised by medium grey tone, steep slopes, uneventex. and corse external drainage.

Typical Land form observed

1. Old Meander
2. Meander Scar
3. Paleochannels

Old Meander & Meander Scar :

It is one of a series of sinuous curves or loops in the course of a mature stream, produce asthe stream swings from side to side in flowing accross its flood-plains or shift its course towards the convex side of the cOridinalcurve. It is the major associated land form in the district, which help in deciding ground water prospects. It is observed in the way of Betwa river, as itc changes its path, & now flowing to the shortest route, by cuttin g that path, which is called meander scar . It is observed near Punchh, some distance before, where Betwa & Dhasan rivef met. It clearly been in the sattellite imagery no.

Paleochannels :

The old courses of the Betwa & Dhasan river have been picked up under the streao-models, on either sides of the Dhasan Lakheri and Betwa river. In the Jhansi district the width of these channels are very from 2̂0 m to over 450 ms. At times, part of thease channel have been occupied by the present day drainage which occurs as mifit stream. The develòpment of Paleochannel on either bank of Dhasan or Betwa, possibly indicate lateral migration of the Betwa river.

The paleo channel in Dhasan terrace appear to be in the hydraulic continuity with the Betwa river and can be the possible for the ground water development.

BASIN MORPHOMETRY

MORPHOMETRIC ANALYSIS OF LAKHERI SUB-BASIN

An attempt was made to study the hydromorphometric analysis of Lakheri sub-basin detailed. It is a apart of Dhasan river basin. The Lakheri sub-basin covers an area of about 1171.0625 sq. km. Then drainage map of sub-basin is shown in Fig- 9 . Various drainage parameters such as (i) Linear aspects of channel system, (ii) Areal aspects of drainage basin & (iii) Relief (gradient) aspects of drainage basis & channel networks, has been studied for the analysis of the Lakheri sub-basin.

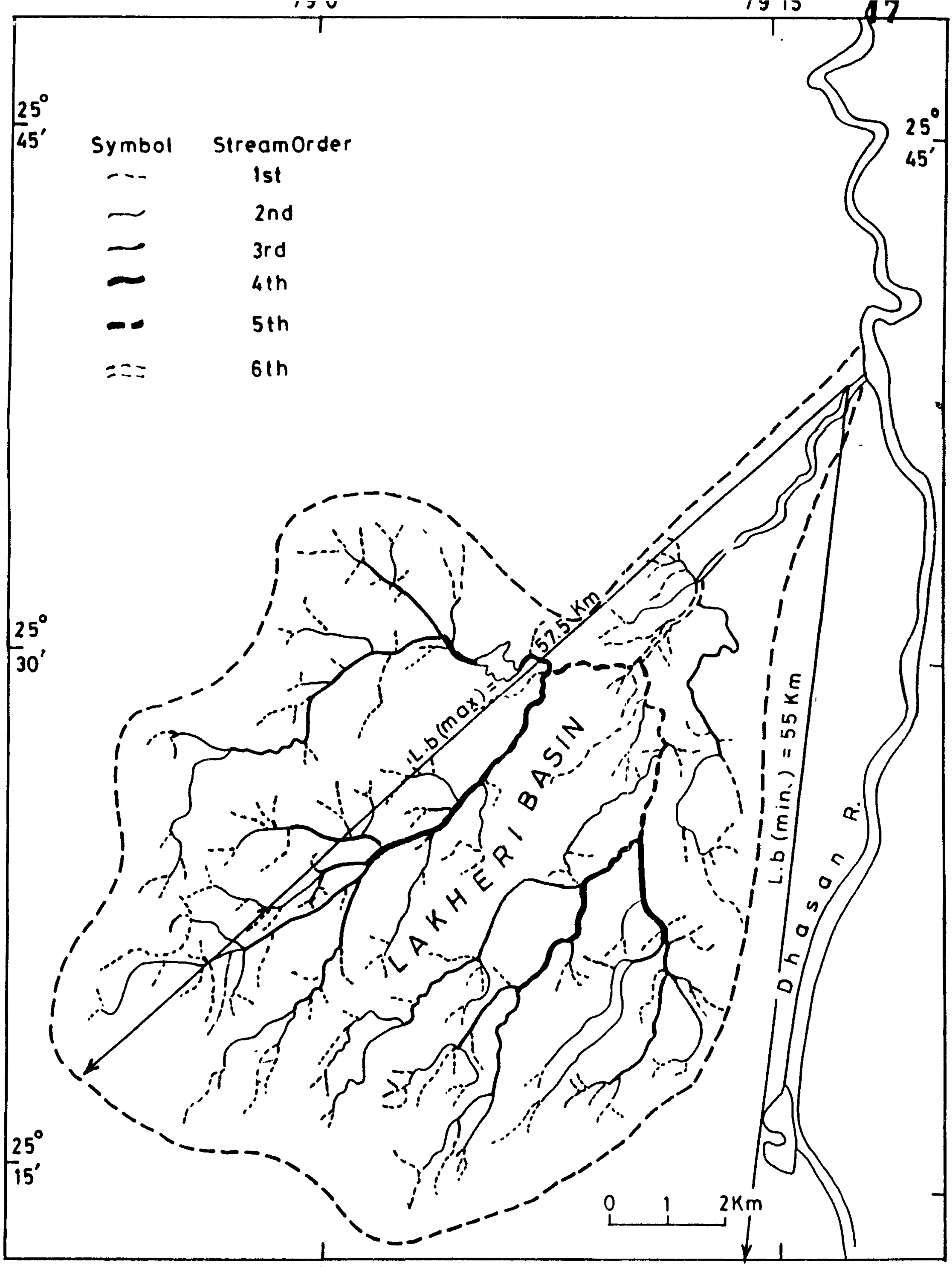
1. Linear aspects of channel system

(i) Stream order:

For ordering the stream, the system introduced by Horton, R.E. (1945) and Later slightly modified by strahler, A.N. (1952) has been followed. Streams upto six order are present in the water-shed (Table IV).

(ii) Stream Numbers:

The law of stream number was introduced by Horton (1945) which states that the number of stream segments of each order form an inverse geometric sequence with order number. Table IV depicts the same things.



Drainage Basin of Lakheri River(Morphometric of Lakheri Basin) of Jhansi District, (U.P.)

FIG-9

TABLE - IV

Order Number	Number of stream (1)	Bifurcation ratio (2)	Number of stream used in the ratio (3)	Product of column (2&3)
I	188	4.177	233	973.241
II	45	3.21	59	189.39
III	14	3.50	18	63
IV	4	2	6	12
V	2	2	3	6
VI	1			
		14.887	-	1243.7262

Mean bifurcation ratio = 2.9774

Wei^hted mean from the total of column 4&3 = 248.7262

TABLE - V

Stream order	Stream length (Km)	Mean stream length (km)	Length ratio
I	505.00	2.66	0.302
II	152.50	3.38	0.458
III	70.00	5.00	0.643
IV	45.00	11.25	0.555
V	25.00	12.50	0.800
VI	20.00	20.00	-
		Total	0.2758

Mean length ratio

(Arithmatic) $= \frac{0.2758}{5}$

$= 0.05516$

(iii) Bifurcation ratio:

It is the ratio of the number of channel segments present in given order to the number of stream segment present in the next higher order.

$$Rb = \frac{N_4}{N_4+1}$$

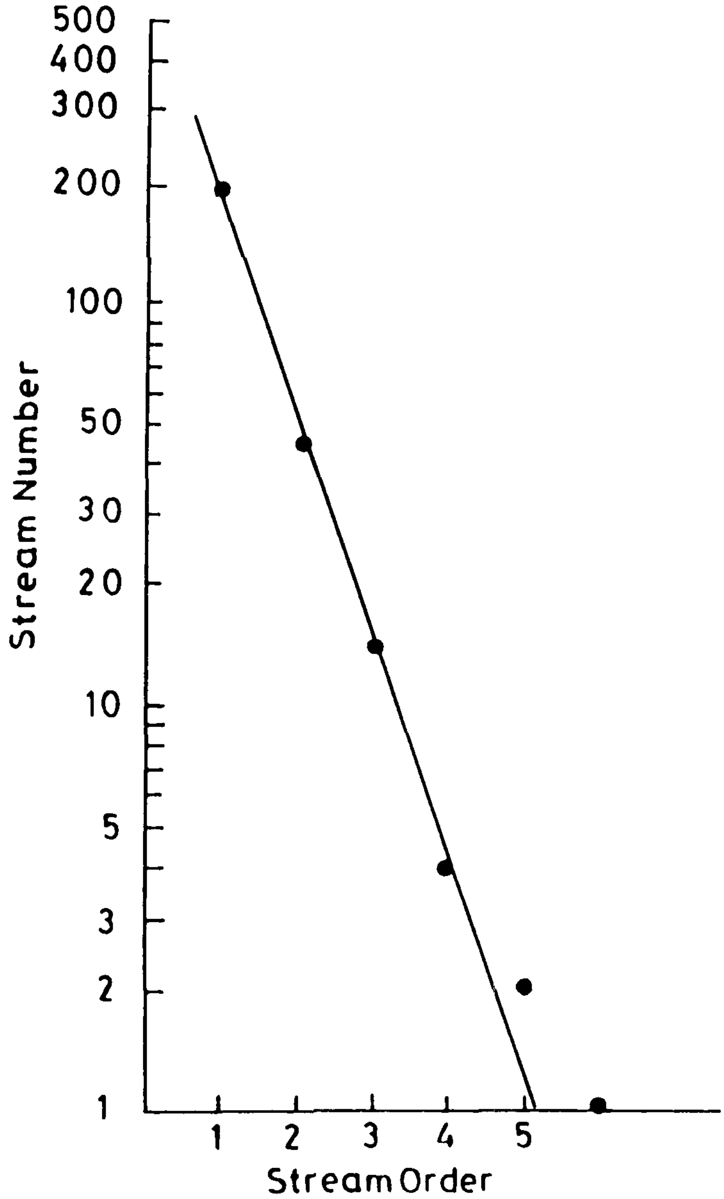
where Rb = bifurcation ratio

Nu = Number of channel segments In the given order

Bifurcation ratio of different orders were determined (Table IV). In general the values of bifurcation ratio are well within the range of 3 to 5 (Chaw V.T., 1964), for the watersheds in which geological structures donot distort the drainage pattern, but at higher orders the sight variation of bifurcation ratio has been observed, which may be on account of the lineament controlled nature of drainages of higher orders. The mean bifurcation ration and weighted mean bifurcation ratio was also calculated (Table IV). A semi log plot was prepared between stream order and number of stream and a best fit line was drawn representing all the points plotted. in which the slope of regression line is bifurcation ratio (Fig 10).

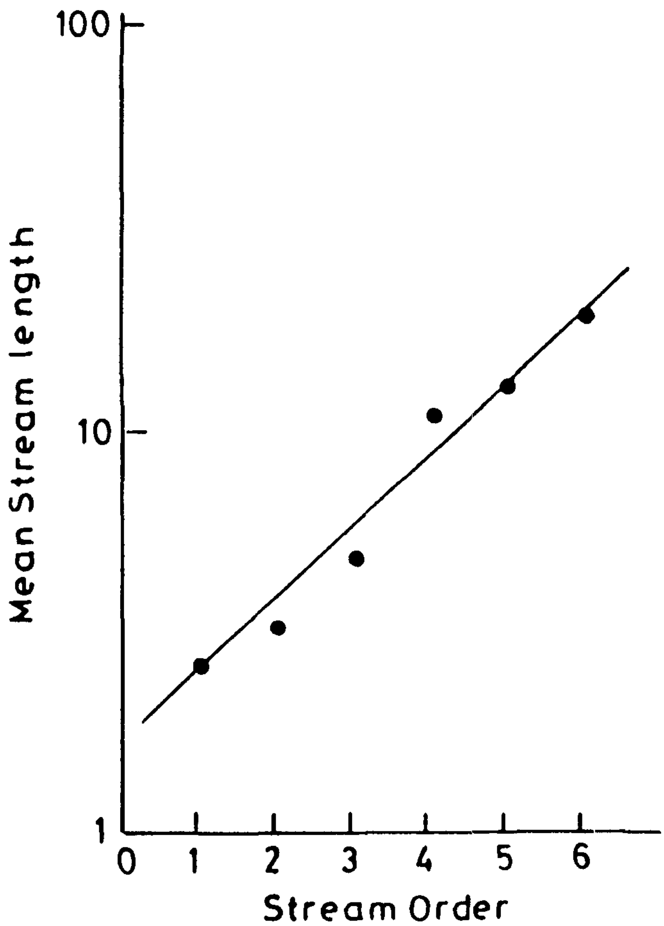
Stream length:

Hortons (1945) law of stream length states that the mean length of stream channel of each successive orders of



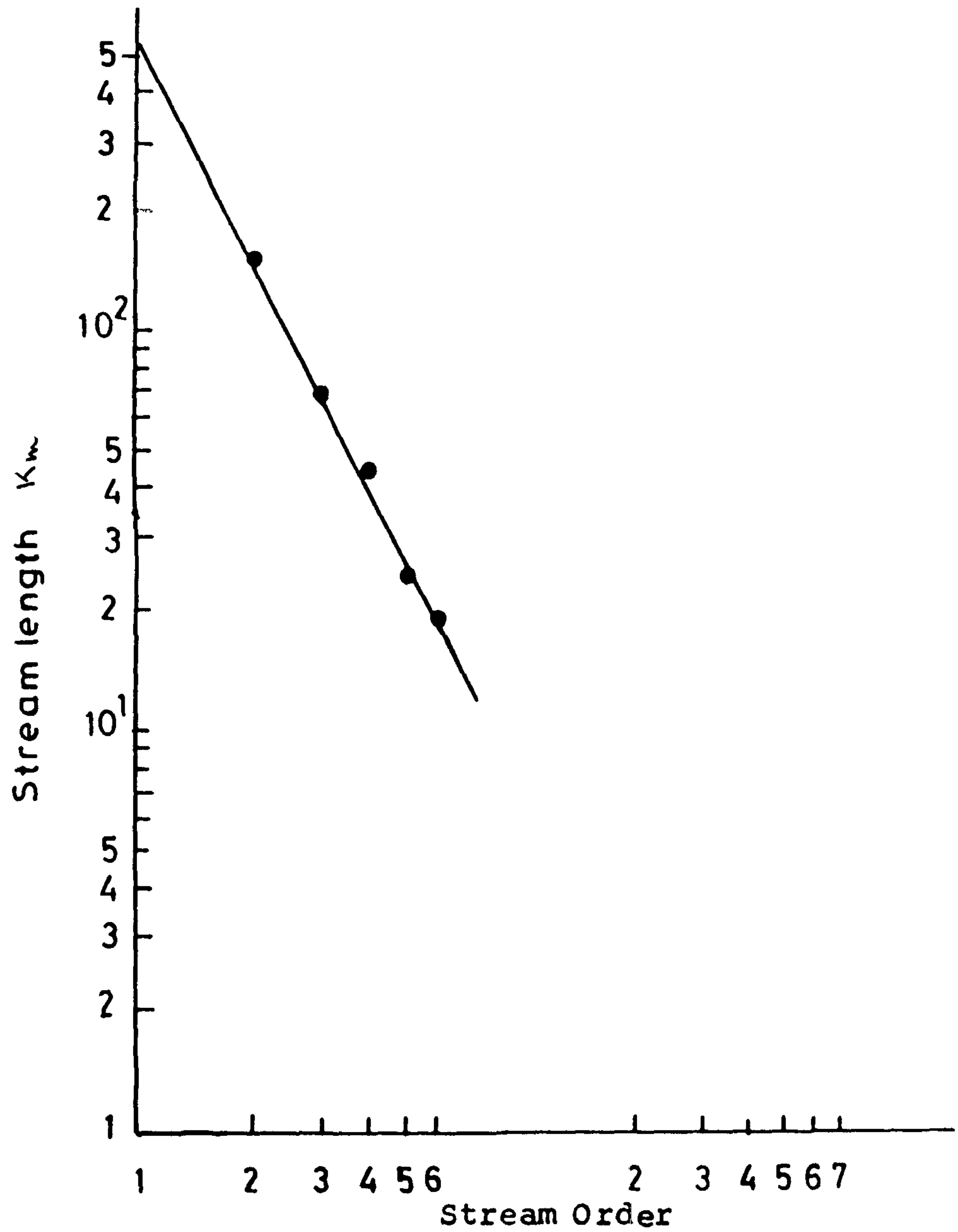
SEMI-LOG PLOTS FOR STREAM NUMBER VS STREAM ORDER

FIG- 10



SEMI-LOG PLOT FOR MEAN STREAM LENGTH VS STREAM ORDER

FIG- 11



LOG-LOG PLOT FOR STREAM ORDER VS STREAM LENGTH

FIG- 12

a basin tend to approximate a direct geometric sequence in which first term is the average length of segments of the first order; Length ratio is the ratio of the mean stream length of the given order to the mean length of the next lower order (Table V) shows the values of cumulative stream length against each order, mean stream length, length ratio and mean length ratio. Mean stream length plotted against the stream order on semi log papers depicts that the mean stream length of stream. Increases with the increase of order (Fig. 11). A log-log plot Fig 12 of stream order. Vs stream length has also been prepared as suggested by Strahter (1957), which shows, As the stream order increases, the cumulative stream length decreases.

AREAL ASPECTS OF DRAINAGE BASIN:

(1) BASIN SHAPE:

The shape parameters are of significant factor in determining the discharge characteristic of channel, which gives an idea or the shape of the basin. The various shape parameters include elongation ratio (Re), form factor (Rf) and circularity ratio (Rc), the various shape parameters are briefly describe as follows:

(i) Form factor : Horton (1932) has introduced this term which is the dimensionless ratio of the basin area to the square of basin length, thus

$$Rf = \frac{Au}{Lb^2}$$

where Au = basin area $(Km)^2$

Lb = basin length (Km)

(ii) <u>Elongation ratio</u>: Schumm, S.A. (1956) has introduced the elongation ratio as the ratio of diametre of a circle of the same area as the basin to the maximum length of basin, thus:

$$Re = \frac{2 / Au/}{Lb\ (Max)}$$

where Au is the basin area (Km^2) and Lb (max), is the maximum length of the basin (Km).

<u>Circularity ratio (Rc)</u>:

Miller, V.C. (1953) used as dimensionless circularity ratio to describe the shape of the basin as the ratio between the area of the basin and area of a Circle having the same circumference as the perimetre of the basin.

$$Rc = \frac{4 \quad . Au}{p^2}$$

Where p indicates perimetre of the basin (Km) and Au is the Area of the basin (Km^2) values of various shape parameters of Lakheri sub-basin have been determined and presented in Table VI .

Drainage density:

According to Horton (1932) the drainage density is obtained by dividing the total stream length to the total basin aea, accordingly

$$\text{Drainage density (Dd)} = \frac{L}{Au}$$

where L is total length of stream (Km)

Au is the area of the basin (Km^2)

The low drainage density is observable in the regions of highly resistant or highly permiable sub-soil materials particularly in the area of thick vegetative cover with low relief, whereas the high drainage density is indication of week or impermiable sub-surface material, mountaineous relief and spars vegetation (Cnaw, 1964). The value of drainage density is observed in table VII .

Stream frequency:

Stream frequency can be obtained by dividing the total number of streams in a given basin to the basin area table VII shows the numerical values of stream frequency.

Infiltration Number:

The infiltration number is the product of the drainage density and stream frequency. It play significant in observing the infiltration character of a basin. It is inversely propor-

TABLE VI

Drainage area $(Km)^2$	Basin perimetre (Km)	Basin length (Km)	Max. Basin length (Km)	Elongation ratio (Re)	Form factor (Rf)	Circularity ratio (Re)
1171.0625	150.75	57.48	57.5	0.671	0.3541	0.647

TABLE VII

Drainage density	Stream frequency	Infiltration number	Length of overland flow
0.698	0.216	0.1507	0.716

TABLE VIII

Maximum basin relief (m)	Relief ratio	Relative relief	Ruggedness number
135	0.002347	0.0895	0.0942

tional to the infiltration capacity of the basin, the values of infiltration number is given in Table VII

The numerical values of drainage density, stream frequency and infiltration number suggest the possibility of high run-off and low infiltration capacity of the basin.

LENGTH OF OVERLAND FLOW:

This term was used by Horton (1945) which is one of the most importants. Independent variable, by virtue of which the hydraulic and physiographic development of drainage basin is affected, Horton has taken approximately equal to the half of the reoproed of drainge density, thus:

$$\text{Length of overland flow } Lg = 1/2 \frac{Au}{L}$$

Table VII shows the determined value of Lg.

RELIEF ASPECTS OF DRAINAGE BASIN AND CHANNEL NETWORK

Channel gradient: It can be determined by dividing the differences in elevations from source to mouth by horizontal distance along the river. Channel gradient of Lakheri sub-basin is 57.5 m/Km.

Maximum basin relief (H): It is obtained by the difference of elevation in between basin out let and singhest point on the perimetre of the basin, (TABLE - VIII)

Relief Ratio (Rh): Scumm (1956) has suggested this term, which is obtained by dividing the maximum basin relief to the maximum basin length

$$Rh = \frac{H}{Lb\ (Max)}$$

where H Indicates maximum basin relief (m) and Lb (max) is maximum length of the basin (m).

Relative Relief (Rhp):

This term was used by Milton, M.A. (1957). Accordingly the relative relief is

$$Rhp = \frac{100\ H}{P}$$

Where H is maximum basin relief (m) and p is perimetre of the basin (m).

Ruggedness number :

Ruggedness number (HD) is the product of maximum basin relief and drainage density (Strahler, 1964).

The values of above mention parameters of relief aspects are presented in Table VIII

The value of relief ratio indicate the operation of more intence erosion on the slopes of basin, which is due to fractured and highly weathered nature of granitic materials.

Reggedness number indicates that the slope steepness is more.

CHAPTER - VI

GEOHYDROLOGY AND GROUND WATER CONDITIONS

General Statement:

The area around Jhansi was mapped for study of the geohydrological units, types of aquifer, their charactristics and ground water flow regimes, the ground water characteristics of the various geohydrological units were correlated with their geomorphological expression to obtain the hydrogeomorphological set-up of the area. The objectives of the study was to evolve the geomorphic parameters for the water targetting in hard rock terrain.

QUANTATIVE GEOHYDROLOGY:

Detailed geohydrological studies were carried out for establishing the aquifer characteristics i.e. the water table behaviour, recuperation capacity, residual draw down and the co-efficient of transissibility, storage and permeability, twenty five (25) dug wells were canvassed with an average of one well per 15 sq. km. (~~Annexure~~ Table - / IX Fig. 13). The wells were so chosen that all the geomorphic units were covered by the inventory, besides maintaining the homogeneity in their aerial distribution.

Water table behaviour recuperation capacity, residual draw down co-efficient of transmissibility, storage and permeability were studied in the area by the following 'Theis Non-Equilibrium Method' (Theis, 1935) and 'Adiyalkar and

Table- IX

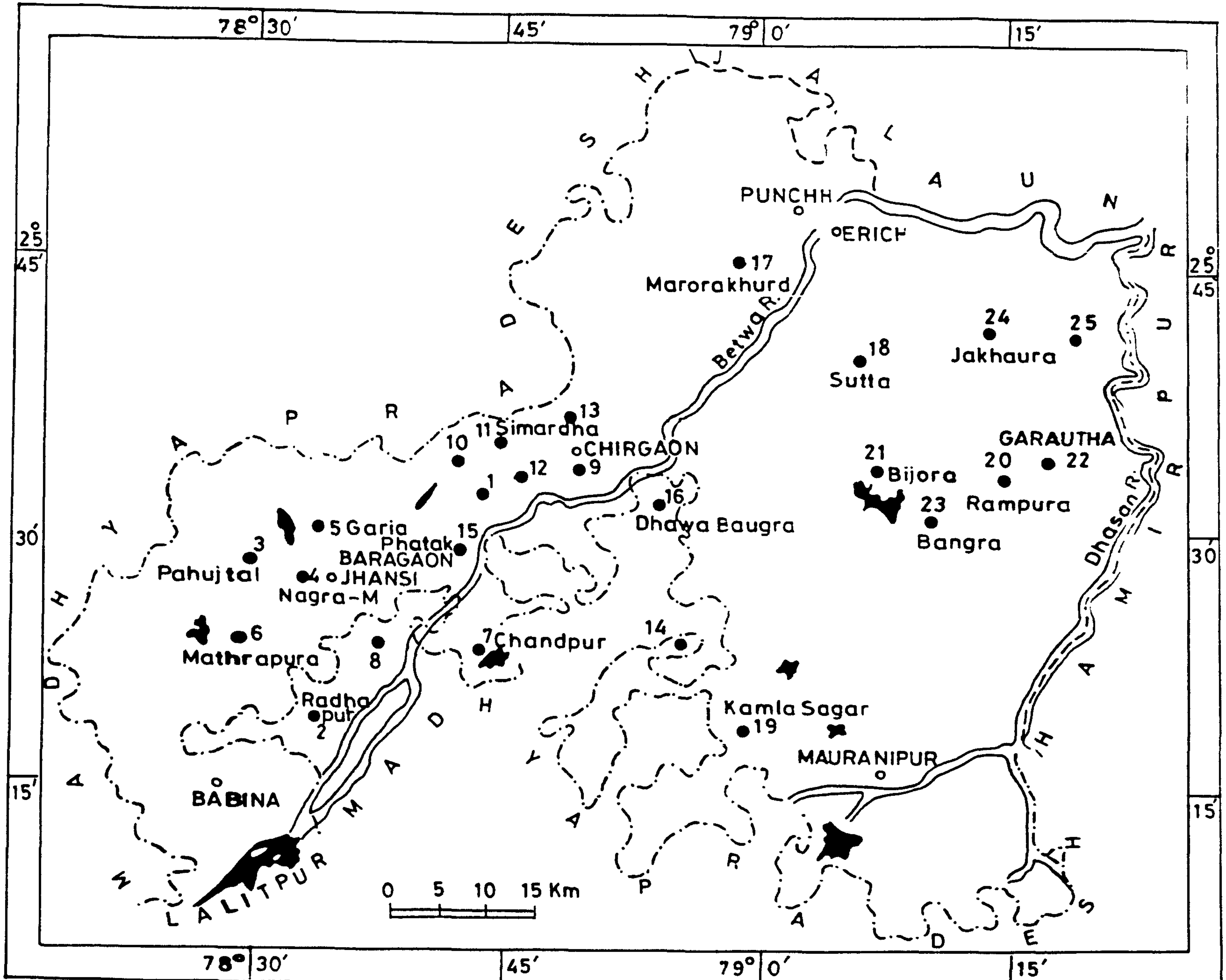
HYDROLOGICAL DETAILS OF WELLS INVENTORIES IN THE AREA JHANSI DISTRICT, U.P.

S.No.	Toposheet No.	Location	Diameter of well (mts)	Depth to water level b.m.p.	Depth to water level b.y.L.	R.L of ground level (mts) Aquifer
1	2	3	4	5	6	7
1.	54 K	Buy a village central raily Jhansi-Manikpur Branch 20 km	3.20	5.80	6.70	120.000 fine Saw silt & clay
2.	54 K	Radhapur(N.H 26) 25 km Jhansi City	2.35	6.80	5.88	134.914 do
3.	54 K	Pahujtal in west Jhansi City 20 km	3.12	8.00	7.70	127.920 do
4.	"	Nagra Mohalla in South of Jhansi City 20.25 km	2.17	7.07	6.09	115.000 do
5.	"	Garia Phatak (Near Railway Crossing) Jhansi Main Line	2.59	6.20	4.70	133.730 do
6.	"	Mathrapur a, 30 km Jhansi(Rail-way crossing)	2.14	7.25	6.55	139.540 do
7.	"	Chandpur 30-35 km Jhansi	2.83	4.02	3.84	159.170 weathered & Frac
8.	"	Kumhava	4.15	9.3?	8.22	151.000 do
9.	"	Grahman Tal	3.07	5.88	7.38	146.000 do

Contd...

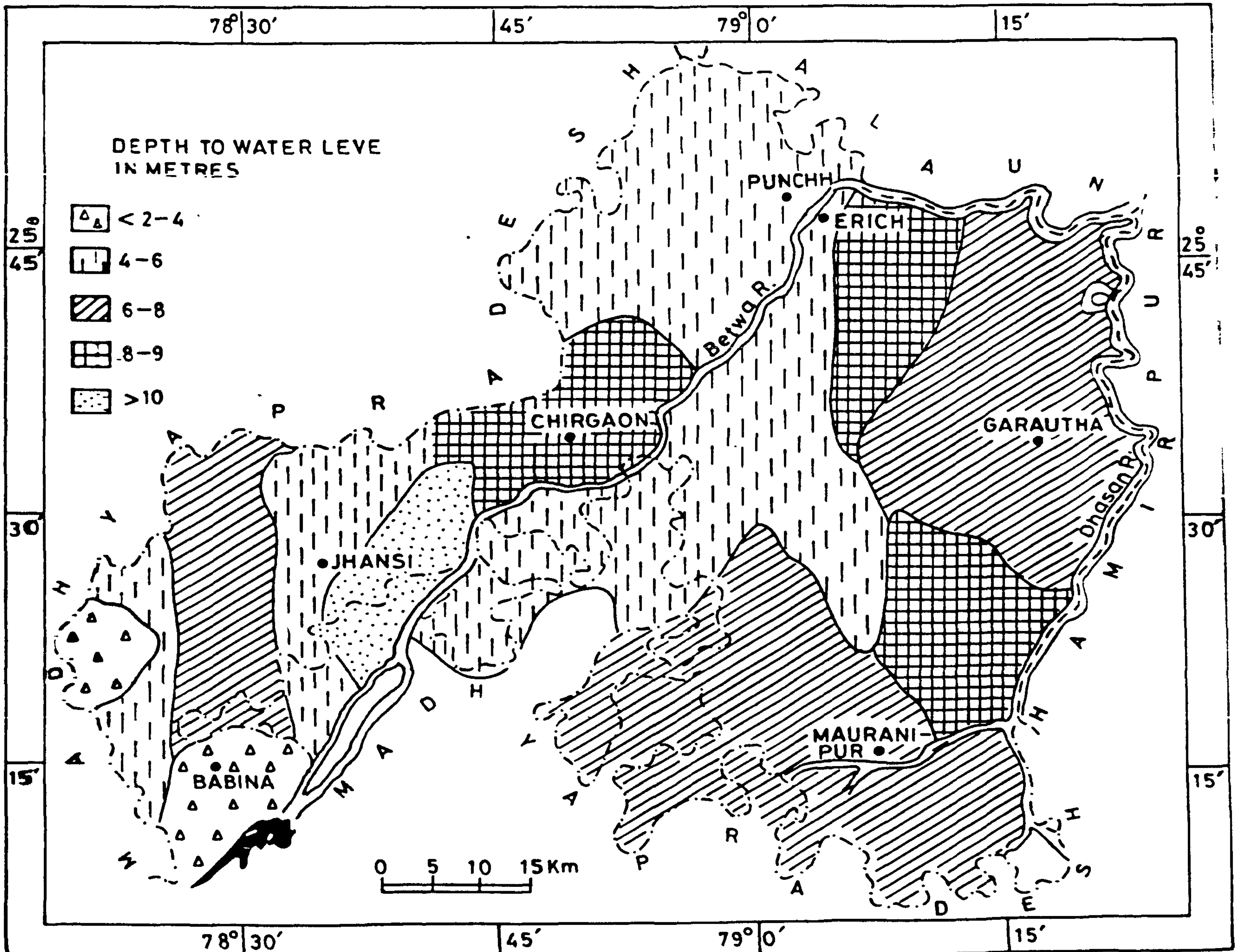
1	2	3	4	5	6	7
10	54 K	Isagarh North of Jhansi 10 km	4.25	6.75	5.95	169.000 do
11	"					
11	"	Simardha near Pahuj(R) 20 km to Jhansi City (NW)	2.65	13.00	12.80	134.000 do
12	54 K	Parari 20 km NW Jhansi	1.92	17.00	16.11	116.000 Saw & gravel
13	52 H/14	Miyanpur SE, Jhansi 30 km	2.10	11.44	9.50	117.000 do
14	52 H/14	Dhamna SE Jhansi 20-35 km	2.40	6.55	6.25	116.000 do
15	52 H/14	Damraum	3.03	7.95	7.83	120.000 do
16	52 H/14	Dhawa Bangra ( ) Jhansi	1.82	7.25	6.44	118.000 Sand & gravel
17	52 H/14	Marora Khurd NE of Jhansi Newr Betwa Basin	1.75	6.20	5.21	117.000 do
18.	52 H/14	Sutta	5.80	7.80	7.50	120.630 do
19.	52 H/14	Kamlasagar	4.00	5.50	5.20	121.000 do
20.	52 H/14	Rampura	4.54	5.54	5.44	117.000 do

1	2	3	4	5	6	7	
21.	52 H/14	Bijora	5.40	7.18	6.56	116.000	do
22.	52 H/14	Nipan	3.60	8.55	8.20	122.000	do
23.	52 H/14	Baugra	2.84	5.06	2.24	118.000	do
24.	52 H/14	Jakhaura	3.26	8.888	8.46	112.000	do
25.	52 H/14	Dhamnoi	2.20	7.06	6.46	114.000	do



MAP SHOWING THE LOCATION OF OBSERVATION WELLS IN THE DISTRICT JHANSI (i.e. STUDY-AREA)

FIG-13



DEPTH OF WATER LEVEL OF THE STUDY AREA(i.e, in parts of Jhansi District, U.P.)

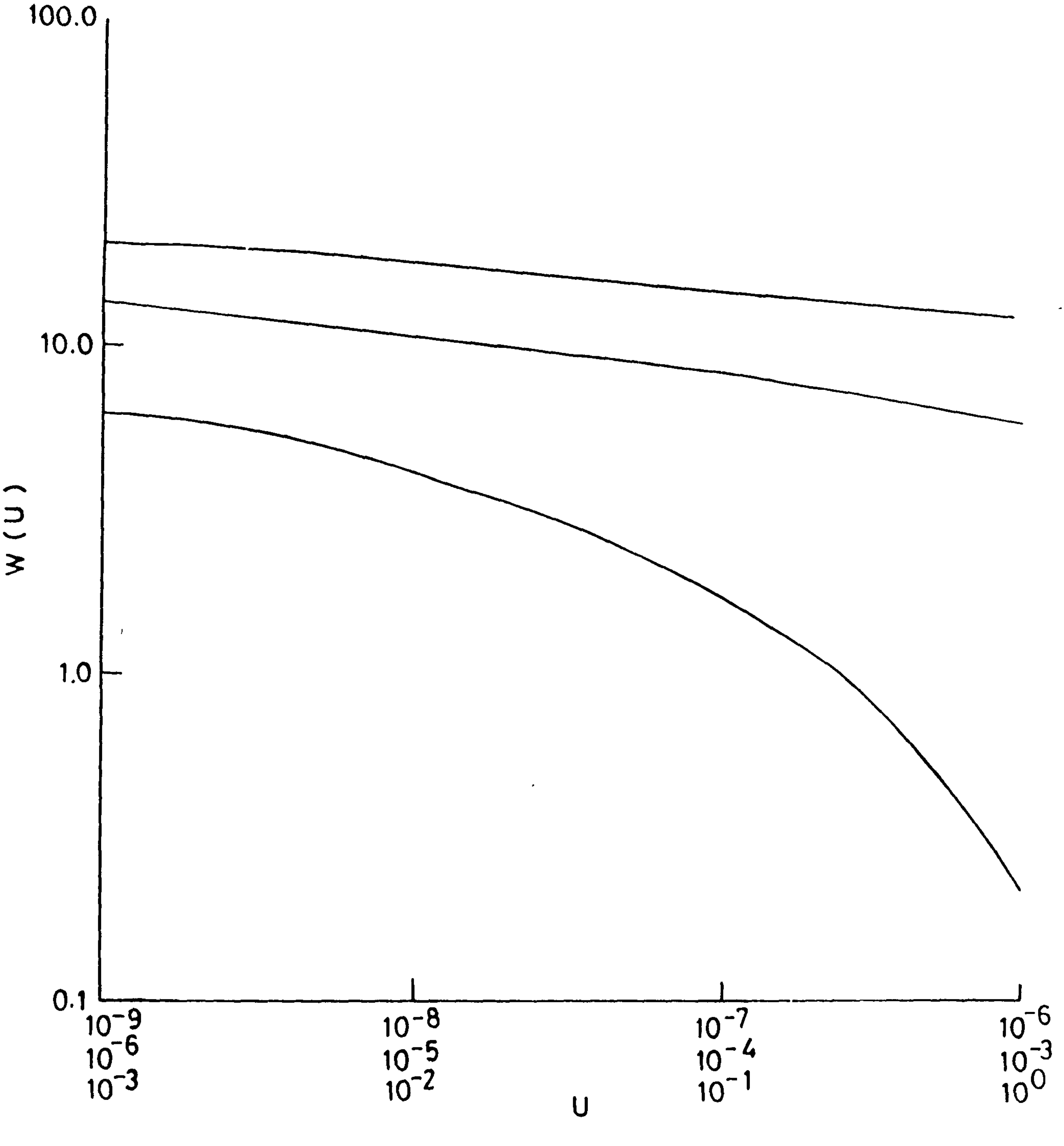
FIG-14

Mani's Method (Sinha, 1972, Pathak, 1978). The heis non-equilibrium method was followed for determination of aquifer parameters in the areas where the sets of pumping and observation wells were available. At places where only pumping (cum observation) wells were available Adiyalkar and Mani's Method was adopted.

(A) <u>Theis non-equilibrium Method</u>:

Pumping test were conducted at five places (Fig. 16, 17, 18, 19) to find out the different aquifer parameter i.e. transmissibility coefficient (T), storage co-efficient (S) and permeability coefficient (K) by theis method. This method was applied on five sets of pumping and observation wells. The steps followed in the field to carry out the test, are listed below.

1. Initial water level in the observation well was measured (In metres), prior to pumping (Annexure/Table, IX)
2. Pumping well (tube well) was started, with uniform discharge (in m^3/day) and the drawdown in the observation well was measured (in meters) with resp to time (in day)
3. For the time-draw down Analysis the theis method was adopted, which is a graphical one based on the superpositions of curves. Wenzel (1942) gave a tabulation of exponential integral written symbolically as W(u) or the well function of u (for values of U from to 9.9).



THEIS TYPE CURVE FOR W(u) VS U

FIG-15

The steps followed in the time-draw-down Analysis are as follows.

3.1 Theis type curve (Fig. 15) was constructed on double log-paper, by plotting values of W(u) against corresponding values of U (Wenzel, 1942).

3.2 Drawdown (S) in meters, was plotted against time (t) in days on another double-log paper, of the same size as for the type curve for five sets of well (Figs. 16, 17, 18, 19, 20)

3.3 Field data plots (~~Figs 21~~ Table/Annex IV) were superimposed over the type curve (Fig. 15) to locate the best fit match, keeping the co-ordinate axes of the two curves parallel in such a way that "S" remains parallel to W(u).

3.4 An arbitrary match point was selected in each curve (Fig. 16 to 20) and noted the co-ordinates of match point in terms of W (u), u, s, and t (Table

4. The data was computed by the following theis equation:-

$$S = \frac{Q}{4 \quad T} \quad W(u)$$

where, S is the drawdown in meters, Q is the discharge in m^3/day; T is the transmissibility co-efficient in m^3/m/day; W(u) is the exponential integral or well function of u and

$u = r^2S/4Tt$, where r is the distance in metre between tubewell and observation well; s is the dimensionaless storage coefficient and t is the time in days, since pumping stanted.

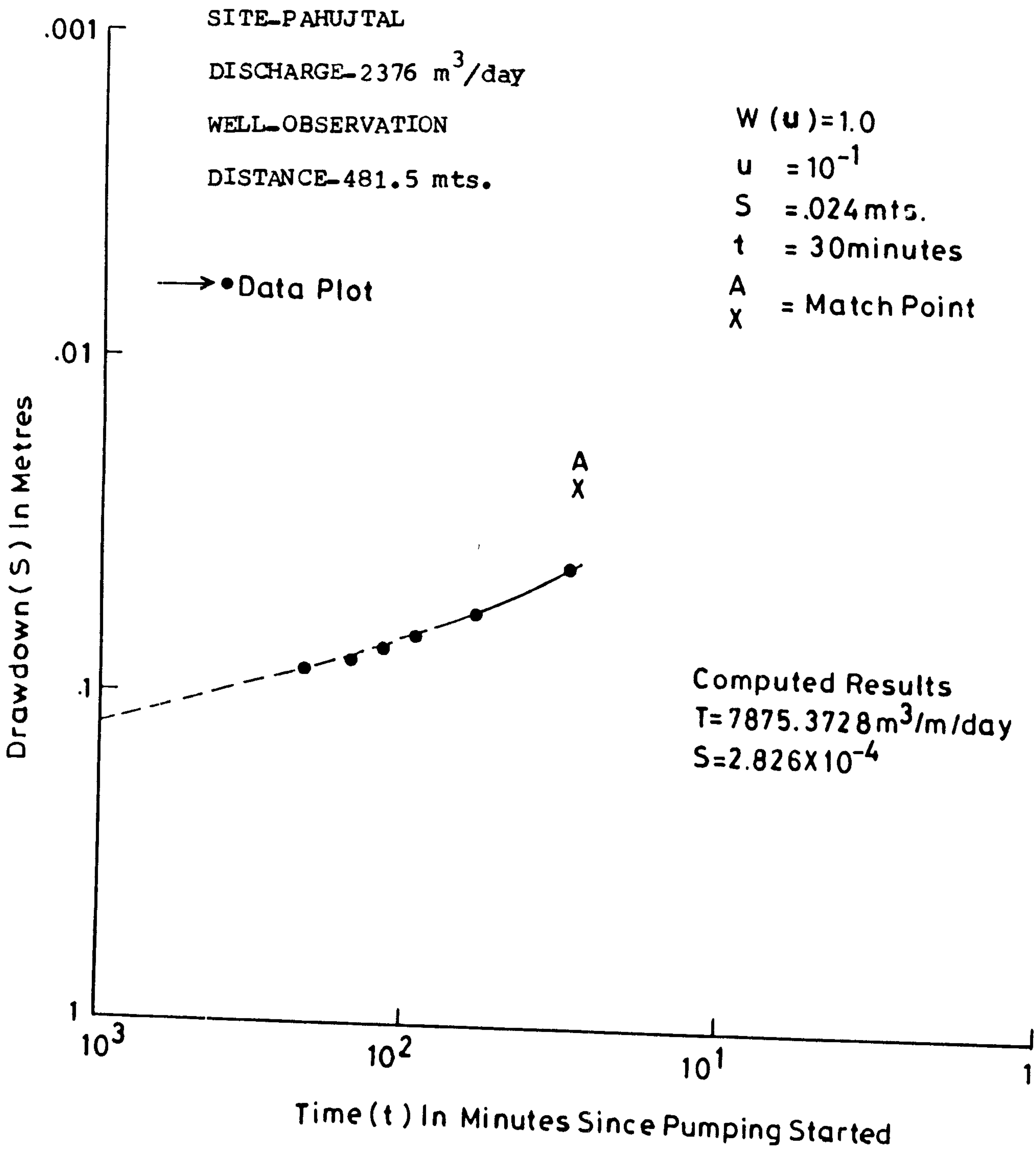
By substituting the values in the 'Theis' Equation "S" and "T" were obtained (~~Table~~/Annexuture - Ia to Ie

(B) ADIYALKAR AND MANI'S SPECIFIC CAPACITY METHOD:

Theis method was applied on the pumping cum-observation (dug-cum-bored) wells filled with electrically driven pumps at three places viz.

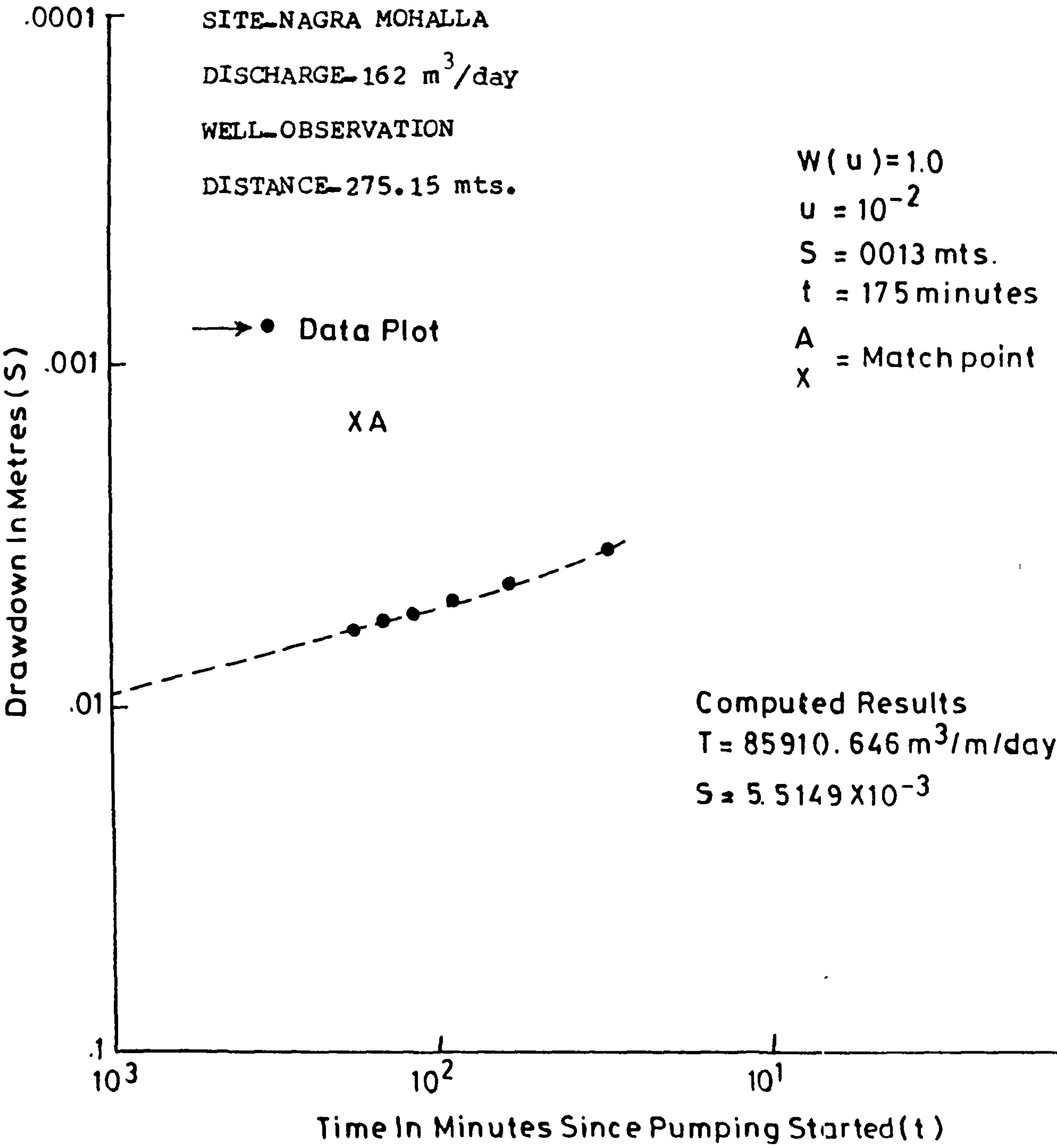
The following steps were adopted to collect the field data (Annexures cum/Table - I) and the computation of T from Adiyalkar and Mani's Method:-

1. Initial water level, in metre, in the well was measured before pumping and the redius of the well was noted.
2. Pump stanted with uniform discharge, noted in m^3/day.
3. Increasing depth to water level in the well measured in metres with time in days for a few period of time.
4. Pump was stoped and recuperation in metres was measured with time in days untill it attained the initial depth to water level.
5. Adiyalkar and Mani gave the following equation to compute the transmissibility coefficient of aquifer:



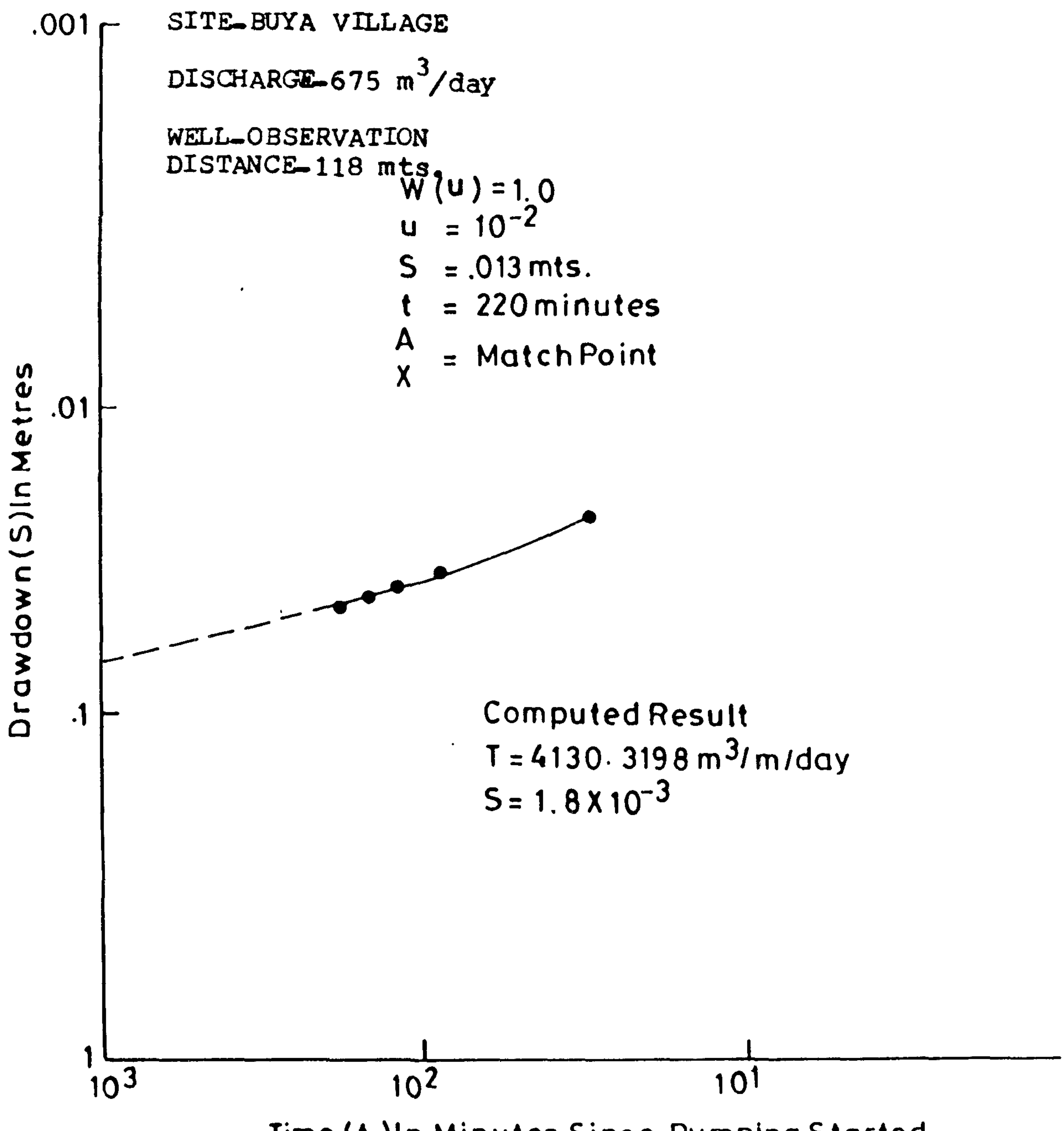
TIME VS DRAWDOWN CURVE (THEIS METHOD)

FIG-16



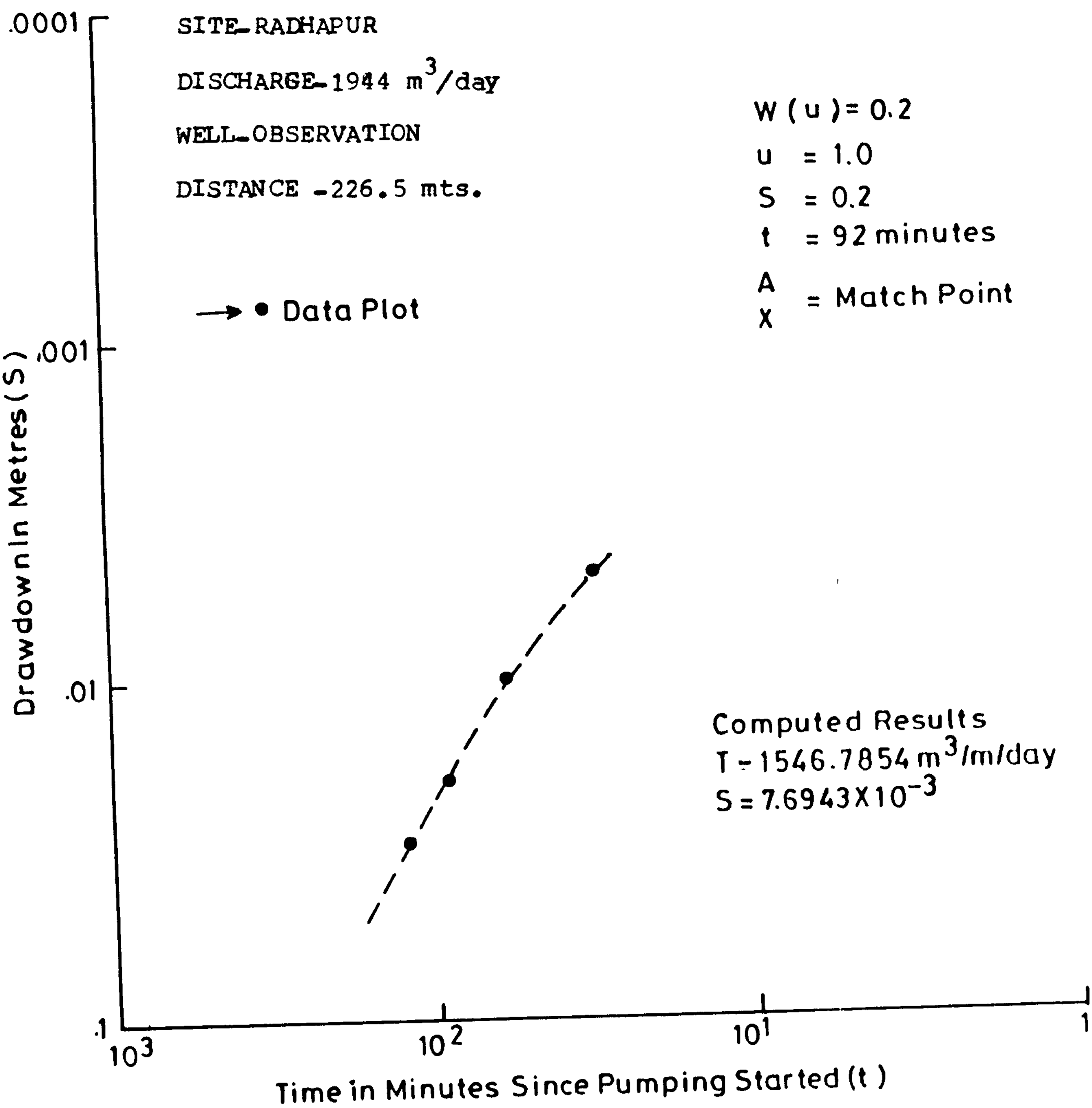
TIME VS DRAWDOWN CURVE (THEIS METHOD)

FIG-17



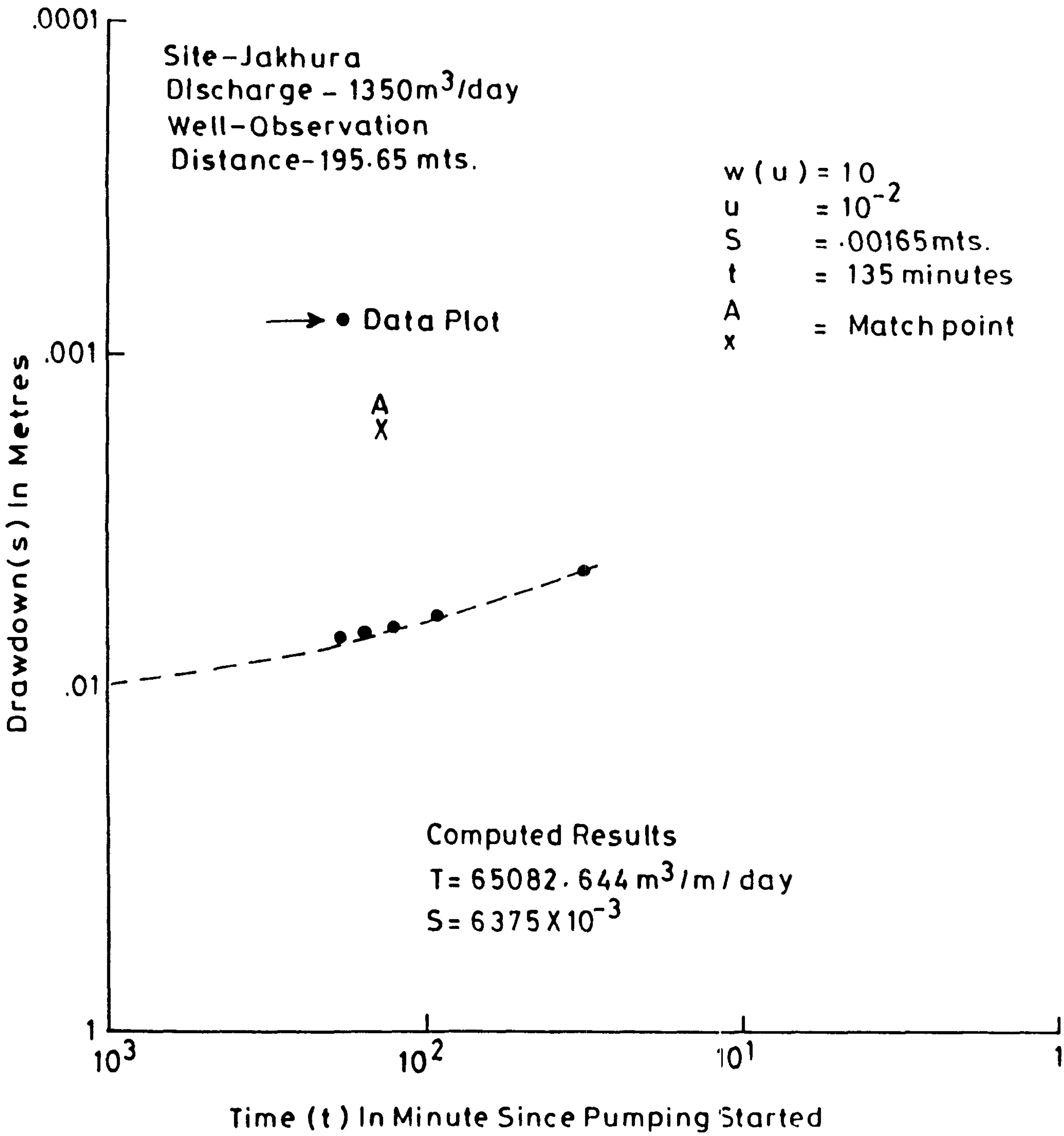
TIME VS DRAWDOWN CURVE (THEIS METHOD)

FIG-18



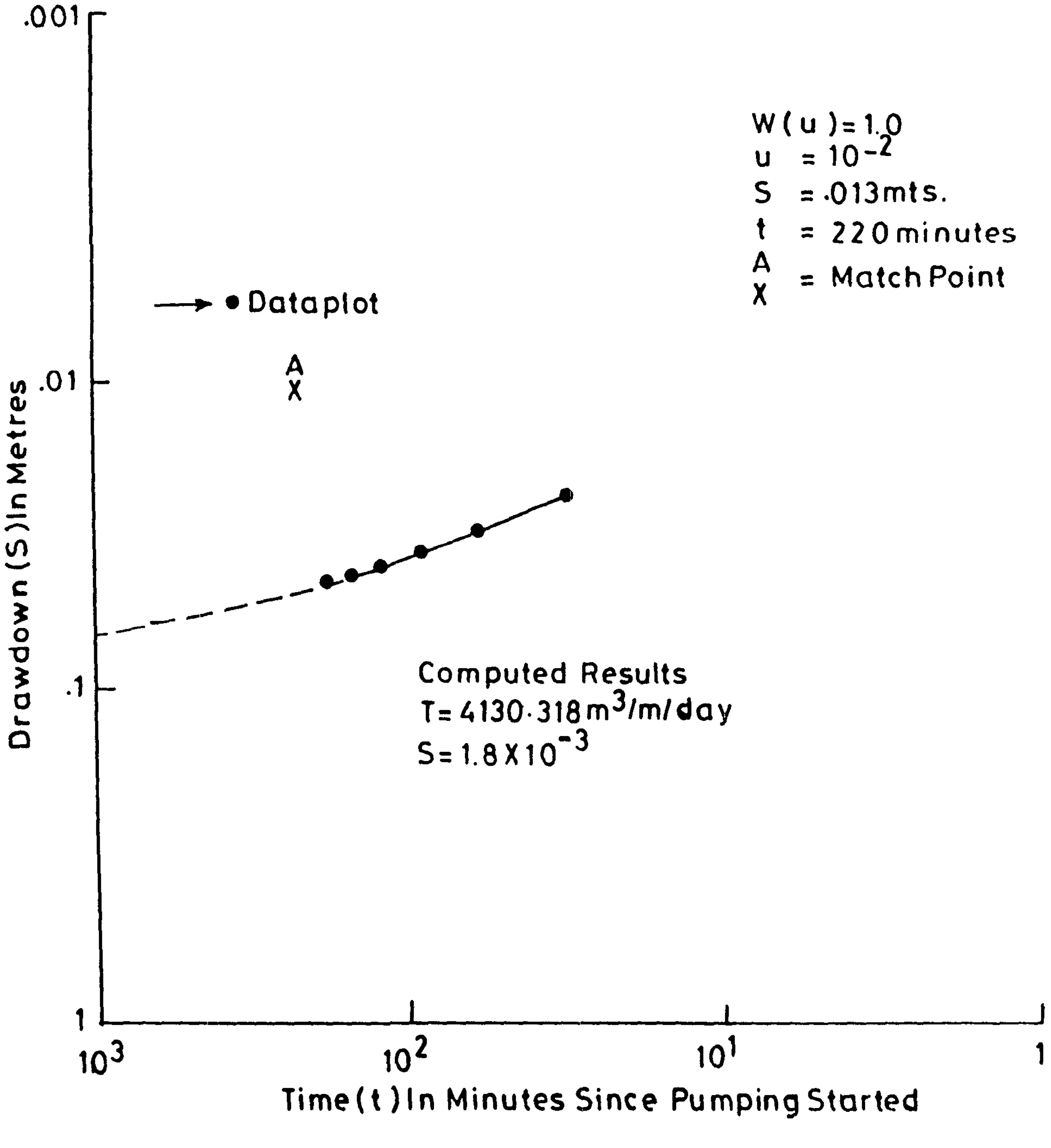
TIME VS DRAWDOWN CURVE (THEIS METHOD)

FIG-19



TIME VS DRAWDOWN CURVE (THEIS METHOD)

FIG-20



TIME VS DRAWDOWN CURVE (THEIS METHOD)

FIG-21

$$T = \frac{Q}{S} 527.7 \log \frac{R}{r}$$

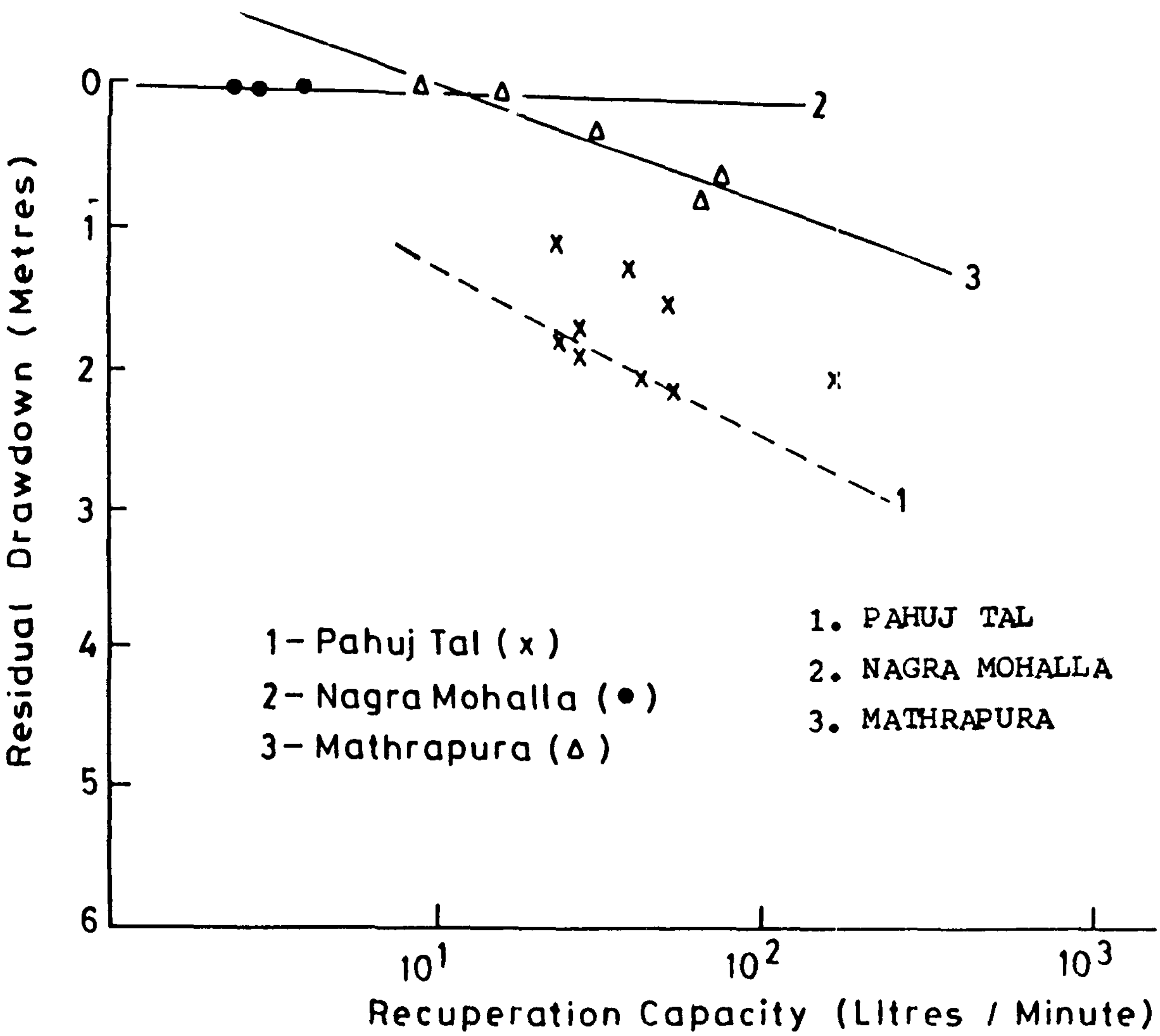
where T is the transmissibility coefficient in $m^3/m/day$; Q is the discharge in m^3/day S is the total drawdown during first hour pumping in metre, R is the radius of influence of the well taken as 250 metre and r is the radius of the well in metre. By substituting the observed values in the Equation the transmissibility co-efficient is computed Table/Annexuture- I)

COMPUTATION OF AQUIFER PERMEABILITY:

Computation of field coefficients of permeability (K) were made using the results of transmissibility coefficients (T) obtained by pumping out water tests' conducted on five tubwells (Theis non-equilibrium method) and three dug-cum bored well (Adiyallcar's and Mani's). A convenient quantity in calculation of ground water flow is T. By subsituting the value of T in the Equation, the value of coefficient of permeability obtained, is given in Table/Annexuture - II)

$$T = K \times b$$

where, T is the transmissibility coefficient in $m^3/m/day$, K is the coefficient of permeability in $m^3/m^2/day$ and b is the saturated aquifer thickness in metres tapped in the well Table/Annexuture- IV).



RECUPERATION CAPACITY VS RESIDUAL DRAWDOWN

FIG- 22

COMPUTATION OF RECUPERATION CAPACITIES OF THE WELLS

Sinha (1972) and Pathak (1978) adopted tabular computation to find out the residual draw down and recuperation capacity. This method was applied on three pumping-cum-observation (dug-cum-bored) well viz. Pahujtol, Nagra Mohalla, Malhpura with the help of the yield characteristic of these wells (Table and recuperation data obtained from these wells (Annexure the recuperation capacity was obtained (Annexure - III The graph were constructed (Fig. 22) by plotting recuperation capacity in litres/m against the residual drawdown, which are inveriably straight lines.

CHAPTER - VII

PHOTO-GEOMORPHIC TECHNIQUES FOR WATER TARGETTING

General Statement:

Semi arid areas like the Bundelkhand region in the state of Uttar Pradesh often exprience acute shortage of water both for drinking and irrigation purposes. The region has varied geology and topography. The common feature controlling the occurrence and movement of the ground water are perious rock, fractured and weathered mantle, quartz reefs, dykes and soil thickness (Mankhand et al. 1981, Seelan, 1983). Jhansi city and districts are located in undulating granitic terrain. The drinking water requirement of the area is met through a combination of surface water schemes, dugwells, tubewells and handpumps. The rapid growth in population and industrial development of the district has led to a severe water crisis. To establish the ground water potentiality in Jhansi city and adjoining area, an attempts has been made to study the ground water conditions through sattelite imagery. Geophysical survey and drilling in various geomorphic units.(FIG-23).

Qualitative and quantitative geohydrological studies carried out in the area around Jhansi, reveal two types of aquifers namely granitic and alluvial aquifers. The granitic aquifers have low potentiality whereas, alluvial aquifers exhibit potentiality from poor to highly potential area. Presents the quantitative potential of the geohydrological units andtheir granulometric parameters.(Table X).

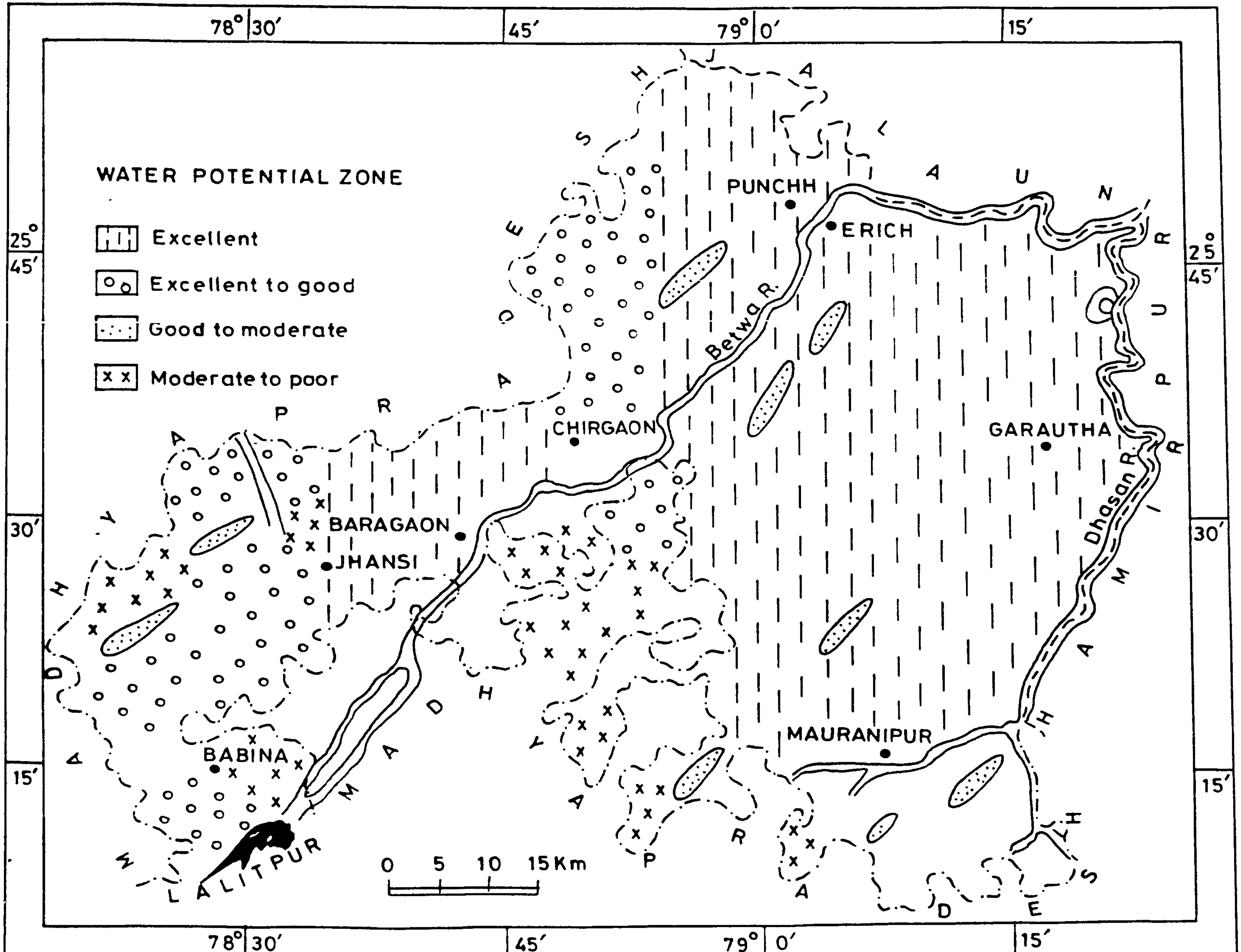


FIG-23 GROUND WATER POTENTIAL ZONE OF THE JHANSI DISTRICT (i.e., Study Area)

TABLE X

GEOHYDROLOGICAL UNITS AND THEIR CHARACTERISTICS

S. No.	Geohydrological Unit	Discharge in litres per hour	Aquifer characteristics
1.	Highly potential Area	70,000 to 200,000	Medium to coarse sand at places very coarse associated with gravels (including abandoned channels)
2.	Potential Area	50,000 to 70,000	Medium to fine sand with kankar at places coarse sand
3.	Fairly Potential Area	25,000 to 50,000	Fine sand and kankar mixed with silty clay
4.	Moderately Potential Area	10,000 to 25,000	Fine sand, clay and kankar as well as weathered granitic residuum
5.	Poorly Potential Area	1,000 to 10,000	Fractured and jointed granite with little weathered granitic residuum

The potentiality index of the area has been correlated with the geomorphological surfaces and units within them. A correlated review of the geomorphological and hydrogeological maps reveal a general correlation between potentiality index and the geomorphic features. The areas occupied by Residual hills and Inselberg complex will have poor potentiality for water targetting. The areas occupied by Lakheri Surface characterised by fluvial terraces, meander scars and palaeochannels will have a potentiality of 50,000 to 70,000 litres per hour. The areas occupied by Dhasan surface will exhibit variable potentialities. A general correlation between surface drainage and hydrogeological potential of the area reveals that the areas with higher drainage densities will have relatively low potential, ranging from (10,000 to 25,000) litres per hour, whereas areas with low drainage density will be potential to highly potential with a range of (50,000 to 200,000) litres per hour.

Taking the above correlation between the geomorphological features and the water potentiality of the area, it can be generalised that water targetting can be attempted through photo-geomorphic interpretation techniques in the Jhansi area. The areas comprising the inselberg complex and Residual Hills will provide poor aquifers. Linear ridge and buried pediplain will be potential. The areas representing the buried pediplain having low drainage densities will be potential areas for well site selection in this hard rock terrain.

Jhansi area is representative of the Bundelkhand granitic province. The geomorphic and geohydrological parameters established at Jhansi can be extrapolated for water targetting in the adjacent hard rock area.

Geohydrological Units:

The occurrence, movement and retrieval of the ground water from the lithounits are primarily based on the granulometric charasteristics of the clastics, perosity permeability and the fracture pattern in the hard rock. In order to study the water bearing charastricsts of the different Geological horizon in the area, 25 open wells were convassed. The brief account of these wells is given in ~~annexure~~ table (IX). In addition lithologs were collected from tubewells, test wells and hand-pump drilling records. The details of the subsurface data collected from drilling records have been given in Annexure/table(I,II).

For the purpose of geohydrological mapping, the water potential zone and Depth to water level maps hasbeen prepared. The masps exhibit two type of aquifer zone based on their water bearing characteristics. Viz. Granitic aquifer and alluvial aquifer. Granitic aquifer comprised the Bundelkhand granite and its weathered mantle. The alluvial aquifer comprise quarternary sediments of Lakheri alluvial formation, Betwa terrace deposits and recent Lakheri Flood plain deposits.

GRANITIC AQUIFER:

The granite below the zone of weathering occurs as hard non-porous and impermeable mass, with poor water yielding capacity. Locally fracturing are present, which provide permeability for the occurrence and movement of groundwater.

The water carrying capacity of the litho-unit is dependent on the incidence of fractures as well as their spacing, disposition.

The vertical lineation serve as channels for groundwater movement to the depths while the inclined and sub-horizontal fractures control the spatial spread of groundwater in the area. Most of the lineation are open at the surface but they progressively tighten at depth, this reduces the water bearing capacity of the fractures beyond the depths of 60 to 80 meters in the area. Thus for the contruction of wells, the granites are poor units. Wherever it is absolutely necessary to construct a well in the rocky terrain, it will be advisable to locate the wells in the zones with high incidence of fractures and the wells should be of large diameters, so as to tap large surface area of the saturated zone. The possibility of water beyond a depth of 60 to 80 meters in the granitic outcrops will be remote. Therefore construction of wells deeper than 60 to 80 meters should not be attempted in this geo-hydrological unit.

The granite near the surface has got a weathered mantle which is buried below the alluvial cover. The thickness of this weathered zone is extremely variable. It is few centimeters near the inselbergs and reaches up to 6to 8 meters in areas beyond the inselberg complex. The weathered granite has variable percentage of clay and fracture incidence, which are reflected by inhomogeneities in the porosity and permeability of the weathered granite. The porosity ranges from (5-25%). The granitic aquifers having high porosity and permeability provide good aquifer zones for groundwater development in the area around Grautha & Erich.

ALLUVIAL AQUIFER:

The alluvium exhibits variable thickness due to uneven basement topography in the area. The maximum thickness recorded in the area is around 80 meters. The lithologs of the tube-wells and hand-pumps constructed in the area have provided valuable informations in respect of the local relationship of superposition and rhythm of sedimentation.

Tje alluvial cover in the area comprises clay, sand and gravel with clacareous concretions in between. At places the alluvium rests directly over the granite but by and large the zone of weathered granite intervenes between the hard rock and the alluvium. For hydrogeological purpose the alluvium has been separated into clay layers and granular zones with thin clay lenses. The granular zone comprises coarse clastics derived from weathered granite residuum and fine sand mixed with clay.

GROUNDWATER CONDITIONS IN THE AREA

The granitic and alluvial aquifers delineated in the area on the basis of the subsurface geohydrological exploration exhibit variable water bearing capacities and geohydrological setting.

GRANITIC AQUIFER

The granitic aquifers comprise weathered granite and hard undecomposed granite basement. The granite has little water carrying or conducting capacity and generally forms aquifuge. Locally where secondary porosity and permeability has been generated by the fracture pattern in the granite, it provides local aquifer zones. The weathered granite forms good aquifers except where interstices and fracture planes are filled with clay. The groundwater in the granitic aquifers occurs under unconfined conditions in fresh granite along fractures. In areas where the weathered mantle of the granite forms the aquifer and is overlain by clay layers of the alluvial units, the water occurs under semi-confined conditions.

ALLUVIAL AQUIFERS

The alluvium has layers of clays and interstratified granular zones. The granular zones comprise gravel and sand with admixture of clay and kankar. The clays in the alluvial aquifers are sticky and plastic comprising kaolinite, illite, montmonillonite in various proportions. They have got a small storage coefficient of 0.0002. The granular zone occurs below the surface of saturation and forms excellent aquifers, in the Quaternary sediments of the Lakheri surface, Betwa terrace deposits and Recent Lakheri Flood Plain Deposits. The granular zones occur at different stratigraphic levels in the area. The groundwater occurs in the granular zones in the southeastern and western part of the area under semi-confined conditions. However, south Jhansi, because of the presence of aquicludes over the granular zones, the aquifers are under confined conditions (peizometric).

DEPTH TO WATER LEVEL:

Pre-monsoon measurements of depth to water level were carried out in the area (Annexure I & II). The depth to water level varies from half a meter to over 15 meters. A comparative study of depth to water level in relation to geomorphological units reveals interesting correlation. The water level is deep in the geomorphic surfaces and units defined as Betwa surface and residual hill and Inselberg complex. The depth to water level is surprisingly shallow i.e. 0.5 meters to 5 meters in the areas occupied by Phasan surface and Buried pediplain zone.

Agarwal, A.K. Mishra, D. ---- Remote Sensing application centre, U.P., Ground water exploration division (U.P.).

Chow, V.T. 1964 Hand Book of Applied Hydrology.

Crawford, A.R. 1970 The Precambrian geochronology of Rajasthan and Bundelkhand, Norther India, Can. Jour. of Earth Sciences, vol. no. 1, pp. 91-110.

Davis, S.N.;& De Wiest, R.J.M. 1966 Hydrology

Deekshatula, B.L., Rajan, Y, S 1984 R. Sensing of Indian Academy of Science Banglore pp 304

Floyd, F, Sabinsjr, 1987 Remote Sensing pp 449

Jhingran, A.G. 1958 The problem of Bundelkhand Granites and Gneisses, Pres. Add., Proc. 45th Indian Sci. Congr., pp.1-33.

Krishnan, M.S. 1982 Geology of India and Burma, 6th edition.

Lilles & T.M. 1979 Remote Sensing & image interpretation, Jonwilley Senpus pp. 612.

Mallet, F.R. 1989 Vindhyan rocks in Bundelkhand, Mem. G.S.I., Means, R.E. & Parcher, J.V. 1963 Physical properties of soils.

Meinzer, O.E. 1949 Hydrology

Sharma, R.P. 1975 New data on the geology of Bundelkhand complex of Central India., Rec. Res. in Geol., vol. 2, pp. 311-346.

Pascoe, E.H. 1950 Manual of geology of India and Burma, vol. 1, Govt. of Ind. Press., Calcutta, pp. þ-483.

Pathak, B.D. 1878 Hydrogeology andgroundwater potential of U.P., C.G.W.B., N.R., Lucknow.

Pichamuthun, C.S. 1967 Precambrian of India in the Precambrians., vol. 3 by Rankama, pp. 59.

Sharma, R.P.C. 1983 Structure & tectonics of Bundelkhand Complex, Central India, Recent Researches in Geology.

Sharma, R.P. 1982 Lithostratigraphy, Structure and petrology of the Bundelkhand Group in Geology of Vindhchol, Hindustan Push. Co. N. Delhi Ed. Ks Voldia S.B. Bhatia, V.K. Gaur.

Sah, D.L. 1983 Progress report for the field season 1962-63 on geohydrological survey in the hard rock andadjacent alluvial areas of Hamirpur district, U.P.,G.S.I

Saxena, M.N.	1953	Agmatities in the Bundelkhand granites and gneisses and the phenomenon of granitisation, Curr. Sci., vol. 22/21, pp. 376-377.
S.N. Pandey	1987	Principle and Application of Photogeology, Publication in India pp. 336.
----------	1957	Structural study of Bundelkhand granite and associated rocks from Kabrai andMauranipur areas of Hamirpur and Jhansi. Res. Bull. of the Punjab Univ., vol. 12, pp. 85-107
Todd, D.K.	1959	Groundwater Hydrology.
Wenzel, L.K.	1942	Methods for determining permeability of water bearing materials with special reference to discharging well method, U.S.G.S. water supply paper 887, Washington, D.C., pp. 192.

Vindhachal by Waldia
Indian Journal of Earth Sciences Volume No. 19,4 Oct. 1992 Indian Society of Earth Science, Calcutta.

ANNEXUTRE - Ia

Pumping Test Field Data of Theis Non-Equilibrium Method

WELL NO. 1

Location	:	BUYA VILLAGE
Test Conducted on	:	20.4.94
Owner of the observation well	:	PWD
Depth to water level in observation well	:	7.71 meters
Diameter of observation well	:	2.30 meters
Measuring point	:	Towards east
Total Depth of observation well	:	10.05 meters
Temperature of water	:	21^{o}C
Discharge of pumping well	:	2500 gallons per hour or 675 m^3/day
Thickness of aquifer zone tapped in pumping well	:	22 meters; Distance : 118 meters

Table observation of time versus drawdown

(Observation well)

S.No.	Time (hrs)	Time in minutes since pumping started	Depth of water level (meters	Drawdown (meters)	Remarks
1.	1100	0	7.710	0.000	Pump started
2.	1130	30	7.737	0.27	
3.	1200	60	7.745	0.035	
4.	1230	90	7.755	0.045	
5.	1300	120	7.757	0.047	
6.	1330	150	7.760	0.050	Pump stopped

WELL NO. 2

Location	:	RADHAPUR
Test conducted on	:	23.4.94
Depth of water level in observation well	:	4.61 meters
Diameter of observation well	:	2.31 meters
Measuring point	:	Towards east
Total Depth of observation well	:	7 meters
Temperature of water	:	21^{o}C
Discharge of pumping well	:	18000 gallons per hour or 1944 m^3/day
Thickness of aquifer zone tapped in pumping well	:	24 meters
Distance between pumping well and observation well	:	226.5 meters

Table of observation of time versus drawdown
(observation well)

S. No.	Time (hrs)	Time in minutes since pumping started	Depth of water level (meters)	Drawdown (meters)	Remarks
1.	1215	0	4.61	0.000	pump started
2.	1245	30	4.615	0.005	
3.	1315	60	4.62	0.010	
4.	1345	90	4.63	0.020	
5.	1415	130	4.64	0.030	
6.	1445	150	4.64	0.030	
7.	1500	165	4.64	0.030	Pump stopped

WELL NO. 3

Location	:	PAHUJ TAL
Test conducted on	:	25.4.94
Owner of the observation well	:	Verma
Depth to water level in observation well	:	4.38 meters
Diameter of observation well	:	1.36 meters
Measuring point	:	Towards south
Total Depth of observation well	:	7.55 meters
Temperature of water	:	22^{o}C
Discharge of pumping well	:	22000 gallons per hour or 2376m^3/day
Thickness of aquifer zone tapped in pumping well	:	24 meters
Distance between pumping well and observation well	:	481.5 meters

Table of observation of time versus drawdown

(observation well)

S.No.	Time (hrs)	Time in minutes since pumping started	Depth of water level (meters)	Drawdown (meters)	Remarks
1.	1215	0	4.38	0.000	Pump started
2.	1245	30	4.423	0.053	
3.	1315	60	4.438	0.058	
4.	1345	90	4.447	0.067	
5.	1415	120	4.455	0.075	
6.	1445	150	4.460	0.080	Pump stopped

WELL NO. 4

Location	:	NAGRA MOHALLA - I
Test conducted on	:	27.4.94
Depth to water level in observation well	:	7.71 meters
Diameter ofobservation well	:	1.67 meters
Measuring point	:	Towards east
Total Depth of observation well	:	7.73 meters
Temperatureof water	:	22.5^{o}C
Discharge of pumping well	:	15000 gallons per hour or 1620 m^3/day
Thickness of aquifer zone tapped in pumping well	:	22 meters
Distance between pumping well and observation well	:	275.15 meters

Table ofobservation of time versus drawdown
(observation well)

S. No.	Time (hrs)	Time in minutes since pumping started	Depth to water level (metres)	Drawdonw (meters)	Ramarks
1.	0530	0	7.71	0.0	Pump started
2.	0600	30	7.7135	0.0035	
3.	0630	60	7.7145	0.0045	
4.	0700	90	7.715	0.005	
5.	0730	120	7.7155	0.0055	
6.	0.800	150	7.7158	0.0058	
7.	0.830	180	7.716	0.006	Pump stopped

WELL NO. 5

Location	:	JAKHAURA
Test conducted on	:	.28.4.94
Depth of water level in observation well	:	15.01 meters
Diameter of observation well	:	2.35 meters
Measuring point	:	Towards east
Total Depth of observation well	:	15.33 meters
Temperature of water	:	21°C
Discharge of pumping well	:	12500 gallons per hour or 1350m^3/day
Thickness of aquifer zone tapped in pumping well	:	32 meters
Distance between pumping well and observation well	:	195.65 meters

Table of observation of time versus drawdown (observation well)

S. No.	Time (hrs)	Time in minutes since pumping started	Depth to water level (meters)	Drawdown (meters)	Remarks
1.	0530	0	15.01	0.0	pump started
2.	0600	30	15.0145	0.0045	
3.	0630	60	15.0155	0.0055	
4.	0700	90	15.016	0.006	
5.	0730	120	15.0165	0.0065	
6.	0800	150	15.0168	0.0068	
7.	0830	180	15.017	0.0070	pump stopped

ANNEXURE - IIa

Field data of recuperation testconducted on dug-cum-bored wells (open wells)

WELL NO. 6

Location : PAHUJTAL

Test conducted on : 28.4.94
Hetri Singh

Total Depth : 17.71 meters

Diameter : 3.83 meters

Average discharge : 1098 m^3/day

Static water level : 4.62 meters

Water level after pumping for 51 minutes : 6.83 meters

Recuperation readings

Time (hrs)	Water level (mts)	Time (hrs)	Water level (mts)
1416	6.83	1520	6.53
1417	6.79	1530	6.50
1418	6.78	1440	6.39
1419	6.78	1555	6.45
1420	6.77	1610	6.42
1423	6.76	1625	6.39
1429	6.72	1705	6.39
1432	6.71	1725	6.22
1423	6.69	17.45	6.10
1440	6.66	1805	6.02
1445	6.64	1835	5.88
1450	6.62	1905	5.80
1455	6.60	1935	5.71
1500	6.59	2005	5.67
1510	6.55		

WELL NO. 7

Location	:	NAGRAMOHALLA
Test conducted on	:	27.4.94
Total depth	:	6.98 meters
Diameter	:	1.75 meter
Average discharge	:	685.44 m^3/day
Static water level	:	6.24 meters
Water level after pumping for 33 minutes	:	6.35 meters

Recuperation reading

Time (hrs)	Water level (mts)
1337	6.36
1342	6.34
1347	6.334
1352	6.33
1357	6.315
1402	6.31
1407	6.30
1412	6.29
1417	6.291
1427	6.29
1437	6.27
1447	6.26
1457	6.254
1507	6.24

IIc

WELL NO. 8

Location	:	MATRAPURA
Test conducted on	:	26.4.1994
		Parakash Singh
Total depth	:	14.60 meters
Diameter	:	2.28 meters
Average discharge	:	962.74 m^3/day
Static water level	:	12.60 meters
Water level after pumping for 4 hours and 30 minutes		

Recuperation readings

Time (hrs)	Water level (mts)
1530	13.50
1531	13.50
1532	13.49
1533	13.48
1534	13.47
1535	13.46
1538	13.42
1541	13.35
1544	13.30
1547	13.26
1550	13.17
1600	13.09
1610	12.98
1620	12.90
1630	12.84
1645	12.77
1700	12.70
1715	12.66
1730	12.60
1750	12.60

ANNEXURE III

Stepwise Calculations of Recuperation Capacities

WELL NO. 6

Open Well at Pahujtal

Static water level (mts) H_1	Time (hrs)	Pumping water level (mts) H_2	Time (hrs)	Water level (mts) H_3	Recuperation (mts) H (H_2 H_3)	Recuperation time (mts) t	Recuperation per minute (mts/minute) $h \frac{H}{t}$	Recuperation capacity (liters/minute) $1000 \frac{D^2h}{4}$	Residual drawdown (mts) $\frac{H_2 + H_3}{2}$ H_1	Recuperation/square metre cross sectional
1	2	3	4	5	6	7	8	9	10	11
4.62	1416	6.38	1420	6.77	0.06	4	0.015	172.883	2.18	15.00
	1420	6.77	1435	6.69	0.08	15	0.005	57.627	2.11	5.00
	1435	6.69	1500	6.59	0.10	25	0.004	46.102	2.02	4.00
	1500	6.59	1540	6.49	0.10	40	0.0025	28.813	1.92	2.50
	1540	6.49	1625	6.39	0.10	45	0.0022	25.356	1.82	2.20
	1625	6.39	1705	6.29	0.10	40	0.0025	28.813	1.72	2.50
	1705	6.29	1805	6.02	0.27	60	0.0045	51.865	1.535	4.50
	1805	6.02	1905	5.80	0.22	60	0.0036	41.492	1.29	3.60
	1905	5.80	2005	5.67	0.13	60	0.0021	24.203	1.115	2.10

WELL NO. 7

Open well at NAGRA MOHALLA

1	2	3	4	5	6	7	8	9	, 10	11
6.24	1337	6.35	1357	6.135	0.035	20	0.0017	4.090	0.092	1.70
	1357	6.315	1417	6.29	0.025	20	0.0012	2.887	0.062	1.20
	1417	6.29	1437	6.27	0.02	20	0.0010	2.406	0.040	1.00
	1437	6.27	1457	6.25	0.02	20	0.0010	2.406	0.020	1,00
	1457	6.25	1507	6.24	0.01	10	0.0010	2.406	0.005	1.00

WELL NO. 8

Open well at MATRAPURA

1	2	3	4	5	6	7	8	9	10	11
12.60	1530	13.54	1535	13.46	0.08	5	0.016	65.351	0.90	16.00
	1535	13.46	1550	13.17	0.29	15	0.019	77.604	0.715	19.00
	1550	13.17	1630	12.84	0.33	40	0.008	32.675	0.405	8.00
	1630	12.84	1700	12.70	0.14	30	0.004	16.337	0.170	4.00
	1700	12.70	1730	12.64	0.06	30	0.002	8.168	0.070	2.00
	1730	12.64	1750	12.60	0.04	20	0.002	8.168	0.020	2.00

TABLE/Annexuture-I

COMPUTATIONAL RESULTS OF ADIYALKAR ANDMANI'S METHOD

S.No.	Well No.	Location	Transmissibility coefficient ($m^3/m/day$)
1	6	Pahujtal	553809.9
2	7	Nagramohalla	807301.8
3	8	Matrapura	2973328.2

TABLE/Annexuture-II

COMPUTATIONAL RESULTS OF COEFFICIENT OF PERMEABILITY (K)

S.No.	Well No.	Location	K ($m^3/m^2/day$)
1	1	Buya Village	188.1112
2	2	Radhapur	64.4489
3	3	Pahujtal	327.9928
4	4	Nagra Mohalla-I	3904.9293
5	5	Jakhaura	2033.8326
6	8	Mathrapura	1486667.98

TABLE/Annexuture- III

CO-ORDINATES OF MATCH POINTS AND COMPUTATIONAL RESULTS OF THEIS NON-EQUILIBRIUM METHOD

Well No.	Location	Co-ordinates of Match Points (X) obtained from the curves					Transmissibility coefficients (T) ($m^3/m/day$)	Storage coefficients(s) (dimensionless)
		W(u)	U	S (Drawdown) mts	time (t) Mints.	time (t) Days		
1.	Buya Village ($25^o 24'.08"$ (Manikpur-Jhansi) line 20 Km Jhansi)	1.1	10^{-2}	0.013	220	0.152	4130.3198	$1.8x10^{-3}$
2.	Radhapur ($25^o 18!06"$-$78^o 24'.06"$)	0.22	1.1	0.021	91	0.0637	1544.7854	$7.6942x10^{-3}$
3.	Pahujtal ($25^o 23'.08"$-$78^o 32'.2"$)	1.1	10^{-1}	0.023	30	0.0208	7874.9921	$2.826x10^{-4}$
4.	Nagra Mohalla ($25^o 24'.02"$-$78^o 34'.08"$	1.1	10^{-3}	0.00150	174	0.1215	85911.002	$5.5149x10^{-3}$
5.	Jakhaura ($25^o 39!.06"$ - $78^o 32'.08"$	1.1	10^{-2}	0.00166	134	0.09375	65081.993	$6.375x10^{-3}$

TABLE/Annexuture- IV

DETAILS OF YIELDS CHARACTERISTICS OF OPEN (DUG-CUM-BORED) WELLS

Location	PAHUJTAL	NAGRA MOHALLA	MATHRAPURA
WELL NO.	6	7	8
Depth to water level (mts)	4.61	6.20	12.59
Total depth of well	17.70	6.88	14.60
Thickness of zone tapped (mts)	13.08	0.72	2.00
Diameter of well	3.80	1.75	3.00
Discharge of well (m^3/day)	1097.99	684.33	960.78
Drawdown 1 hour (mts)	2.21	0.10	0.41
Recuperation (mts) I hour	0.28	0.08	0.71
II hour	0.40	-	0.90
Method of Lifting	Diesel Pump	Electric Pump	Diesel pump
Aquifer tapped	Wheathered granites	Weathered granite	Weathered granite

~~TABLE~~/Annexuture – V

RESISTIVITY RANGE FOR VARIOUS LITHOUNITS (MISHRA et al, 1987)

FORMATION	RESISTIVITY RANGE (In Ohm-m)
1. Surface soil (wet to dry)	2.6 - 60
2. Clay (wet)	5.0 - 10
3. Saturated medium to coarse sand	20.0 - 50
4. Weathered and semi-weathered granite (Saturated)	10.0 - 50
5. Fractured and jointed granite (water bearing)	30 - 300
6. Dry fractures/fresh granite basement	300